Stereo Analyst ®
User's Guide

- when it has to be right

Leica Geosystems

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Table of Contents

Table of Contents iii
List of Figures ix
List of Tables xi
Preface xiii

About This Manual xiii
Example Data xiii
Tour Guide Examples xiii
Creating a Nonoriented DSM xiii
Creating a DSM from External Sources xiii
Checking the Accuracy of a DSM xiv
Measuring 3D Information xiv
Collecting and Editing 3D GIS Data xiv
Texturizing 3D Models xiv
Documentation xiv
Conventions Used in This Book xiv
Bold Type xiv
Mouse Operation xiv
Paragraph Types xvi

Theory 1

Introduction to Stereo Analyst 3

Introduction 3
About Stereo Analyst 4
Stereo Analyst Menu Bar 4
Stereo Analyst Toolbar 6
Stereo Analyst Feature Toolbar 8
Next 9

3D Imaging 11

Introduction 11
Image Preparation for a GIS 13
Using Raw Photography 13
Geoprocessing Techniques 15
Traditional Approaches 18
Example 1 18
Example 2 18
Example 3 18
Example 4 19

Example 5 19
Geographic Imaging 19
From Imagery to a 3D GIS 21
Imagery Types 22
Workflow 22
Defining the Sensor Model 23
Measuring GCPs 23
Automated Tie Point Collection 24
Bundle Block Adjustment 24
Automated DTM Extraction 24
Orthorectification 25
3D Feature Collection and Attribution 25
3D GIS Data from Imagery 27
3D GIS Applications 27
Next 30

Photogrammetry 31

Introduction 31
Principles of Photogrammetry 31
What is Photogrammetry? 31
Types of Photographs and Images 34
Why use Photogrammetry? 35
Image and Data Acquisition 35
Scanning Aerial Photography 37
Photogrammetric Scanners 37
Desktop Scanners 38
Scanning Resolutions 38
Coordinate Systems 40
Terrestrial Photography 42
Interior Orientation 44
Principal Point and Focal Length 44
Fiducial Marks 45
Lens Distortion 46
Exterior Orientation 47
The Collinearity Equation 49
Digital Mapping Solutions 51
Space Resection 51
Space Forward Intersection 52
Bundle Block Adjustment 53
Least Squares Adjustment 56
Automatic Gross Error Detection 59
Next 59

Stereo Viewing and 3D Feature Collection 61

Introduction 61
Principles of Stereo Viewing 61
Stereoscopic Viewing 61
How it Works 62

Stereo Models and Parallax 64
X-parallax 64
Y-parallax 66
Scaling, Translation, and Rotation 67
3D Floating Cursor and Feature Collection 69
3D Information from Stereo Models 70
Next 72

Tour Guides 73

Creating a Nonoriented DSM 75

Introduction 75
Getting Started 76
Launch Stereo Analyst 76
Adjust the Digital Stereoscope Workspace 76
Load the LA Data 77
Open the Left Image 78
Adjust Display Resolution 80
Zoom 80
Roam 82
Check Quick Menu Options 83
Add a Second Image 86
Adjust and Rotate the Display 88
Examine the Images 88
Orient the Images 89
Rotate the Images 91
Adjust X-parallax 94
Adjust Y-parallax 96
Position the 3D Cursor 97
Practice Using Tools 100
Zoom Into and Out of the Image 100
Save the Stereo Model to an Image File 101
Open the New DSM 102
Adjusting X Parallax 103
Adjusting Y-Parallax 104
Cursor Height Adjustment 105
Floating Above a Feature 106
Floating Cursor Below a Feature 107
Cursor Resting On a Feature 108
Next 109

Creating a DSM from External Sources 111

Introduction 111

Getting Started 113
Load the LA Data 114
Open the Left Image 114
Add a Second Image 116
Open the Create Stereo Model Dialog 117
Name the Block File 118
Enter Projection Information 119
Enter Frame 1 Information 121
Apply the Information 125
Open the Block File 126
Next 127

Checking the Accuracy of a DSM 129

Introduction 129
Getting Started 130
Open a Block File 130
Open the Stereo Pair Chooser 132
Open the Position Tool 135
Use the Position Tool 136
First Check Point 136
Second Check Point 139
Third Check Point 140
Fourth Check Point 141
Fifth Check Point 142
Sixth Check Point 143
Seventh Check Point 144
Close the Position Tool 145
Next 146

Measuring 3D Information 147

Introduction 147
Getting Started 148
Open a Block File 148
Open the Stereo Pair Chooser 150
Take 3D Measurements 152
Open the 3D Measure Tool and the Position Tool 152
Take the First Measurement 154
Take the Second Measurement 160
Take the Third Measurement 162
Take the Fourth Measurement 164
Take the Fifth Measurements 165
Save the Measurements 168
Next 169

Collecting and Editing 3D GIS Data 171

Introduction 171

Getting Started 172

Create a New Feature Project 172
Enter Information in the Overview Tab 172
Enter Information in the Features Classes Tab 173
Enter Information into the Stereo Model 179

Collect Building Features 183
Collect the First Building 183
Collect the Second Building 189
Collect the Third Building 195

Collect Roads and Related Features 198
Collect a Sidewalk 198
Collect a Road 201

Collect a River Feature 205

Collect a Forest Feature 208
Collect a Forest Feature and Parking Lot 210

Check Attributes 216

Next 220

Texturizing 3D Models 221

Introduction 221

Getting Started 221
Explore the Interface 221

Loading the Data Sets 222

Texturizing the Model 223
Texturize a Face In Affine Map Mode 223
Texturize a Perspective-Distorted Face 226

Editing the Texture 230

Tiling a Texture 233
Adding the Texture to the Tile Library 233
Tiling Multiple Faces 233
Scaling the Tiles 234
Add a new Image to the Library 235
Autotiling the Rooftop 236

Reference Material 239

Feature Projects and Classes 241

Introduction 241

Stereo Analyst Feature Project and Project File . 241

Stereo Analyst Feature Classes 244
General Information 244

Point Feature Class 245
Polyline Feature Class 246
Polygon Feature Class 247
Default Stereo Analyst Feature Classes 248

Using Stereo Analyst ASCII Files. 255

Introduction 255
ASCII Categories 255
Introductory Text 255
Number of Classes 255
Shape Class Number 255
Shape Class 2 258
Shape Class N 258
ASCII File Example 258

The Stereo Analyst STP DSM 263

Introduction 263
Epipolar Resampling 263
Coplanarity Condition 263
STP File Characteristics 264
STP File Example 266

References 269

Introduction 269
Works 269

Glossary 275

Introduction 275
Numerics 275
Symbols 275
Terms 276

Index 291

List of Figures

Figure 1: Accurate 3D Geographic Information Extracted from Imagery 13
Figure 2: Spatial and Nonspatial Information for Local Government Applications 16
Figure 3: 3D Information for GIS Analysis 20
Figure 4: Accurate 3D Buildings Extracted using Stereo Analyst 26
Figure 5: Use of 3D Geographic Imaging Techniques in Forestry 27
Figure 6: Topography 31
Figure 7: Analog Stereo Plotter 32
Figure 8: LPS Project Manager Point Measurement Tool Interface 33
Figure 9: Satellite 34
Figure 10: Exposure Station 36
Figure 11: Exposure Stations Along a Flight Path 36
Figure 12: A Regular Rectangular Block of Aerial Photos 37
Figure 13: Overlapping Images 37
Figure 14: Pixel Coordinates and Image Coordinates 40
Figure 15: Image Space and Ground Space Coordinate System 41
Figure 16: Terrestrial Photography 43
Figure 17: Internal Geometry 44
Figure 18: Pixel Coordinate System vs. Image Space Coordinate System 45
Figure 19: Radial vs. Tangential Lens Distortion 46
Figure 20: Elements of Exterior Orientation 48
Figure 21: Omega, Phi, and Kappa 48
Figure 22: Space Forward Intersection 52
Figure 23: Photogrammetric Block Configuration 54
Figure 24: Two Overlapping Photos 62
Figure 25: Stereo View 63
Figure 26: 3D Shapefile Collected in Stereo Analyst 64
Figure 27: Left and Right Images of a Stereopair 64
Figure 28: Profile View of a Stereopair 65
Figure 29: Parallax Comparison Between Points 65
Figure 30: Parallax Reflects Change in Elevation 66
Figure 31: Y-parallax Exists 67
Figure 32: Y-parallax Does Not Exist 67
Figure 33: DSM without Sensor Model Information 68
Figure 34: DSM with Sensor Model Information 69
Figure 35: Space Intersection 71
Figure 36: Stereo Model in Stereo and Mono 72
Figure 37: X-Parallax 104
Figure 38: Y-Parallax 104
Figure 39: Cursor Floating Above a Feature 107
Figure 40: Cursor Floating Below a Feature 108
Figure 41: Cursor Resting On a Feature 109
Figure 42: Epipolar Geometry and the Coplanarity Condition 264

List of Tables

Table 1: Stereo Analyst Digital Stereoscope Workspace Menus 5
Table 2: Stereo Analyst Toolbar 6
Table 3: Stereo Analyst Feature Toolbar 8
Table 4: Scanning Resolutions 39
Table 5: Interior Orientation Parameters for Frame 1, la_left.img 123
Table 6: Exterior Orientation Parameters for Frame 1, la_left.img 123
Table 7: Interior Orientation Parameters for Frame 2, la_right.img 124
Table 8: Exterior Orientation Parameters for Frame 2, la_right.img 125
Table 9: Stereo Analyst Default Feature Classes 249

Preface

About This Manual

The *Stereo Analyst® User's Guide* provides introductions to Geographic Information Systems (GIS), three-dimensional (3D) geographic imaging, and photogrammetry; tutorials; and examples of applications in other software packages. Supplemental information is also included for further study. Together, the chapters of this book give you a complete understanding of how you can best use Stereo Analyst in your projects.

Example Data

Data sets are provided with the Stereo Analyst software so that your results match those in the tour guides.

Example data is optionally loaded during the software installation process into the <IMAGINE_HOME>\examples\Western directory. <IMAGINE_HOME> is the variable name of the directory where Stereo Analyst and ERDAS IMAGINE® reside. When accessing data files, you replace <IMAGINE_HOME> with the name of the directory where Stereo Analyst and ERDAS IMAGINE are loaded on your system.

A second data set is provided on the data CD that comes with Stereo Analyst. This data set, <IMAGINE_HOME>\examples\la is used in some of the tour guides in this book.

Tour Guide Examples

This book contains tour guides that help you learn about different components of Stereo Analyst. All of the tour guides were created using color anaglyph mode. If you want your results to match those in the tour guides, you should switch to color anaglyph mode before starting. To do so, you select **Utility -> Stereo Analyst Options -> Stereo Mode -> Stereo Mode -> Color Anaglyph Stereo**.

The following is a basic overview of what you can learn by following the tour guides provided in this book. You do not need to have ERDAS IMAGINE installed on your system to use the tour guides.

Creating a Nonoriented DSM

In this tour guide, you are going to create a nonoriented (that is, without map projection information) digital stereo model (DSM) from two independent IMAGINE Image (.img) files. You can learn to use your mouse to manipulate the data resolution and to correct parallax.

Creating a DSM from External Sources

In this tour guide, you are going to use two images to create an LPS Project Manager block file (*.blk). To create it, you must provide interior and exterior orientation information, which correspond to the position of the camera as it captured the image. This information is readily available when you purchase data from providers.

Checking the Accuracy of a DSM

In this tour guide, you are going to work with an LPS Project Manager block file. You can type coordinates into the Position tool and see how the display drives to that point. Then, you can visualize the point in stereo (in the Main View or OverView) and in mono (in the Left and Right Views).

Measuring 3D Information

In this tour guide, you are going to work with an LPS Project Manager block file that has many stereopairs. Using the 3D Measure tool, you can digitize points, lines, and polygons. These measurements are recorded in units corresponding to the coordinate system of the image, which is in meters. You can also get more precise information such as angles and elevations.

Collecting and Editing 3D GIS Data

In this tour guide, you are going to set up a new feature project, which includes selecting a stereopair. You can then collect features from the stereopair. You are also going to select types of features to collect. Also, you can learn how to create a custom feature class. You can learn how to use the feature collection and editing tools, as well as the different modes associated with feature collection.

Texturizing 3D Models

In this tour guide, you can learn how to add realistic textures to your models. You first obtain digital imagery of the building or landmark, then you map that imagery to the model using Texel Mapper in Stereo Analyst.

Documentation

This manual is part of a suite of on-line documentation that you receive with ERDAS IMAGINE software. There are two basic types of documents, digital hardcopy documents which are delivered as PDF files suitable for printing or on-line viewing, and On-Line Help Documentation, delivered as HTML files.

The PDF documents are found in <IMAGINE_HOME>\help\hardcopy. Many of these documents are available from the Leica Geosystems Start menu. The on-line help system is accessed by clicking on the Help button in a dialog or by selecting an item from a Help menu.

Conventions Used in This Book

Bold Type

In Stereo Analyst, the names of menus, menu options, buttons, and other components of the interface are shown in bold type. For example:

"In the Select Layer To Add dialog, select the **Files of type** dropdown list."

Mouse Operation

When asked to use the mouse, you are directed to click, double-click, Shift-click, middle-click, right-click, hold, drag, etc.

- Click—designates clicking with the left mouse button.

- Double-click—designates rapidly clicking twice with the left mouse button.
- Shift-click—designates holding the Shift key down on your keyboard and simultaneously clicking with the left mouse button.
- Middle-click—designates clicking with the middle mouse button.
- Right-click—designates clicking with the right mouse button.
- Hold—designates holding down the left (or right, as noted) mouse button.
- Drag—designates dragging the mouse while holding down the left mouse button.

Stereo Analyst has additional mouse functionality:

- Control + left—designates holding both the Control key and the left mouse button simultaneously. This adjusts cursor elevation.
- x + left—designates holding the x key on the keyboard and the left mouse button simultaneously while moving the mouse left and right. This adjusts x-parallax.
- y + left—designates holding the y key on the keyboard and the left mouse button simultaneously while moving the mouse up and down. This adjusts y-parallax.
- c + left—designates holding the c key on the keyboard and the left mouse button simultaneously while moving the mouse up and down. This adjusts cursor elevation.

For the purpose of completing the tour guides in this manual, we assume that you are using a mouse equipped with a rolling wheel where the middle mouse button usually exists. You use this wheel to zoom into more detailed areas of the image displayed in the stereo views. If your mouse is not equipped with a rolling wheel, then you can use the middle mouse in the same context, except where noted.

Left mouse button

Rolling wheel or middle mouse butto

Right mouse button

Paragraph Types

The following paragraphs are used throughout this book:

These paragraphs contain strong warnings or important tips.

These paragraphs direct you to the ERDAS IMAGINE or Stereo Analyst software function that accomplishes the described task.

These paragraphs lead you to other areas of this book or other Leica Geosystems manuals for additional information.

NOTE: Notes give additional instruction.

Blue Box

These boxes contain technical information, which includes theory and stereo concepts. The information contained in these boxes is not required to execute steps in the tour guides or other chapters of this manual.

Theory

Introduction to Stereo Analyst

Introduction

Unlike traditional GIS data collection techniques, Stereo Analyst saves you money and time in image preparation and data capture. With Stereo Analyst, you can:

- Collect true, real-world, three-dimensional (3D) geographic information in one simple step, and to higher accuracies than when using raw imagery, geocorrected imagery, or orthophotos.
- Use timesaving, automated feature collection tools for collecting roads, buildings, and parcels.
- Attribute features automatically with attribute tables (both spatial and nonspatial attribute information associated with a feature can be input during collection).
- Use high-resolution imagery to simultaneously edit and update your two-dimensional (2D) GIS with 3D geographic information.
- Collect 3D information from any type of camera, including aerial, video, digital, and amateur.
- Measure 3D information, including 3D point positions, distances, slope, area, angles, and direction.
- Collect X, Y, Z mass points and breaklines required for creating triangulated irregular networks (TINs), and import and export in 3D.
- Create DSMs from external photogrammetric sources.
- Open block files for the automatic creation and display of DSMs.
- Directly output and immediately use your ESRI 3D Shapefiles in ERDAS IMAGINE and ESRI Arc products.

Stereo Analyst is designed for you with the following objectives in mind:

- Provide an easy-to-use airphoto/image interpretation tool for the collection of qualitative and quantitative geographic information from imagery.
- Provide a fast and optimized 3D stereo viewing environment.
- Bridge the technological gap between digital photogrammetry and GIS.
- Provide an intuitive tool for the collection of height information.

- Provide a tool for the collection of geographic information required as input for a GIS.

About Stereo Analyst

Before you begin working with Stereo Analyst, it may be helpful to go over some of the menu options and icons located on the interface. You use these throughout the tour guides that follow.

Stereo Analyst is dynamic. That is, menu options, buttons, and icons you see displayed in the Digital Stereoscope Workspace change depending on the tasks you can potentially perform there. This is accomplished through the use of dynamically loaded libraries (DLLs).

> ***Dynamically Loaded Libraries***
>
> A DLL is used when you start a new application, such as a Feature Project or import/export utility. Until you request an option, the system resources required to run it need not be used. Instead, they can be put to use in increasing processing speed.

Stereo Analyst Menu Bar

The menu bar across the top of the Stereo Analyst Digital Stereoscope Workspace has different options depending on what you have displayed in the Workspace.

If you have a feature project displayed, the options are different than if you have a DSM displayed. For example, the **Feature** menu, feature collection tools, and feature editing tools are not enabled unless you are currently working on a feature project.

Similarly, the tools available to you at any given time depend on what you currently have displayed in the Workspace. For example, if you are working with a single stereopair, and not an block file, you cannot use the Stereo Pair Chooser.

The full complement of menu items follows.

For additional information about each of the Stereo Analyst tools, see the On-Line Help.

Table 1: Stereo Analyst Digital Stereoscope Workspace Menus

File	Utility	View	Feature	Raster	Help
New >	Terrain Following Cursor	Show/Hide the cursor tracking tools	Feature Project Properties...	Undo Raster Edit	Help...
Open >	Fixed Cursor	Stereo Pair Chooser...	Undo Feature Edit	Left Image >	Navigation Help...
Save Top Layer	Maintain Constant Cursor Z	Invert Stereo	Cut	Right Image >	Installed Component Information...
Export >	Left Only Mode	Update from Fallback	Copy		Installed Graphics And Driver Information...
View to Image...	Right Only Mode	Fit Scene To Window	Paste		About Stereo Analyst...
Close All Layers	Rotation Mode	Reset Zoom and Rotation	Show XYZ Vertices		
Exit Workspace	Block Image Path Editor	Set Scene To Default Zoom	Show All Features		
	Create Stereo Model Tool...	Set Scene To Specified Zoom...	Hide All Features		
	3D Measure Tool...		Show 3D Feature View		
	Position Tool...		2D Snap		
	Geometric Properties...		3D Snap		
	Stereo Analyst Options...		Boundary Snap		
			Right Angle Mode		
			Parallel Line Mode		
			Stream Digitizing Mode		
			Polygon Close Mode		
			Reshape		
			Extend Polyline		
			Remove Line Segment		
			Add Element		
			Select Element		
			3D Extend		
			Import Features...		
			Export Features...		

Stereo Analyst Toolbar

The Stereo Analyst toolbar, like the menu bar, has dynamic icons that are active or inactive depending on your configuration and what displays in the Workspace.

Table 2: Stereo Analyst Toolbar

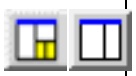
	New	Click this icon to open a new, blank Digital Stereoscope Workspace.
	Open	Click this icon to open an IMAGINE Image (.img), block file (.blk), or Stereopair (.stp) file in the Digital Stereoscope Workspace.
	Save	Click this icon to save changes you have made to your feature projects.
	Choose Stereopair	Click this icon to open the Stereo Pair Chooser dialog. From there, you can select other stereopairs to view in the Digital Stereoscope Workspace.
	Clear the Stereo View	Click this icon to clear the Digital Stereoscope Workspace of images and any features you have collected.
	Image Information	Click this icon to obtain information about the top raster layer displayed in the Digital Stereoscope Workspace. Information includes cell size, rows and columns, and other image details.
	Fit Scene	Click this icon to fit the entire stereo scene in the Main View. If your default is set to show both overlapping and nonoverlapping areas, both are displayed in the stereo view. You can use **Mask Out Non-Stereo Regions** in the **Stereo View Options** category of the Options dialog to see only those areas that overlap.
	Revert to Original	Click this icon to return the scene back to its original resolution and rotation.
	Zoom 1:1	Click this icon to adjust the scene to a 1:1 screen pixel to image pixel resolution.
	Cursor Tracking	Click this icon to open the Left View and the Right View. These small views allow you to see the left and right images of the stereopairs independently.

Table 2: Stereo Analyst Toolbar (Continued)

	3D Feature View	Click this icon to open the 3D Feature View. This view allows you to see features that you have digitized in three dimensions. You can change the color of the model, the background color in the 3D Feature View, as well as add textures from the original imagery to the model. You can also export the model so that it can be used in other applications.
	Invert Stereo	Click this icon to reverse the display of the Left and Right images. This makes tall features appear shallow; shallow features appear tall. You may have to click this icon to correct the way a stereopair displays in the Digital Stereoscope Workspace.
	Update Scene	Click this icon to update the scene with the full resolution. This button is only active when the **Use Fallback Mode** option in the **Performance** category is set to **Until Update**. For more information, see the On-Line Help.
	Fixed Cursor Mode	Click this icon to enable the fixed cursor mode. When you are in fixed cursor mode, you can use the mouse to move the image in the Main View; however, the cursor does not change position in X, Y, or Z.
	Create Stereo Model	Click this icon to open the Create Stereo Model dialog. With it, you can create a block file from external sources. You simply need two independent images and camera information (available from the data vendor) to create the block file.
	3D Measure Tool	Click this tool to take measurements in a stereopair. The 3D Measure tool is automatically placed at the bottom of the Digital Stereoscope Workspace. Measurements can be points, polylines, or polygons, and have X, Y, and Z coordinates. You can also measure slope with the 3D Measure tool.
	Position Tool	Click this icon to open the Position tool. The Position tool is automatically placed at the bottom of the Digital Stereoscope Workspace. The Position tool gives you details on the coordinate system of the image or stereopair displayed in the Digital Stereoscope Workspace.
	Geometric Properties	Click this icon to show the geometric properties of the image displayed in the Workspace. Geometric properties include projection, camera, and raster information.

Table 2: Stereo Analyst Toolbar (Continued)

	Rotate	Click this icon to create a target that enables you to rotate the image(s) displayed in the Digital Stereoscope Workspace. You click to place a target in the image. Then you adjust the position of the image using an axis.
	Left Buffer	Click this icon to move the left image (of a stereopair) independently of the right image. This option is not active when you have a block file (.blk) displayed.
	Right Buffer	Click this icon to move the right image (of a stereopair) independently of the left image. This option is not active when you have a block file (.blk) displayed.

All operations performed using the toolbar icons can also be performed with the menu bar options.

Stereo Analyst Feature Toolbar

Stereo Analyst is also equipped with a feature toolbar. These tools allow you to create and edit features you collect from your DSMs. Stereo Analyst has built-in checks that determine whether you are creating or editing features; therefore, icons are only enabled when they are usable. Table 3 shows the Stereo Analyst feature tools.

Table 3: Stereo Analyst Feature Toolbar

	Select	Click the Select icon to select an existing feature in a feature project. You can then use some of the feature editing tools to change it.
	Box Feature	Click this icon to drag a box around existing features in a feature project. You can then perform operations on multiple features at once.
	Lock/Unlock	Click the unlocked icon to lock a feature collection or editing tool for repeated use. When you are finished, click the locked icon to unlock the tool.
	Cut	Click this icon to cut features or vertices from features.
	Copy	Click this icon to copy a selected feature.
	Paste	Click this icon to paste a feature you have cut or copied.
	Orthogonal	Click this icon to create features that have only 90 degree angles. The tool restricts the collection of features to only 90 degrees.

Table 3: Stereo Analyst Feature Toolbar (Continued)

	Parallel	Click this icon to create features of parallel lines. This tool is useful to digitize roads.
	Streaming	Click this icon to enable stream mode digitizing. This allows for the continuous collection of a polyline or polygon feature without the continuous selection of vertices.
	Polygon Close	Click this icon to complete a building or other square or rectangular feature after collecting only three corners.
	Reshape	Click this icon to reshape an existing feature. You can then click on any one of the vertices that makes up the feature to adjust its position.
	Polyline Extend	Click this icon to add vertices to the end of an existing feature.
	Remove Segments	Click this icon to remove segments from existing line features.
	Add Element	Click this icon to add an element to an existing feature.
	Select Element	Click this icon to select a specific element of a feature, but not the entire feature.
	3D Extend	Click this icon to extend the corners of a feature to the ground.

Next

Next, you can learn how 3D geographic imaging is used in various GIS applications.

3D Imaging

Introduction

The collection of geographic data is of primary importance for the creation and maintenance of a GIS. If the data and information contained within a GIS are inaccurate or outdated, the resulting analysis performed on the data do not reflect true, real-world applications and scenarios.

Since its inception and introduction, GIS was designed to represent the Earth and its associated geography. Vector data has been accepted as the primary format for representing geographic information. For example, a road is represented with a line, and a parcel of land is represented using a series of lines to form a polygon. Various approaches have been used to collect the vector data used as the fundamental building blocks of a GIS. These include:

- Using a digitizing table to digitize features from cartographic, topographic, census, and survey maps. The resulting features are stored as vectors. Feature attribution occurs either during or after feature collection.

- Scanning and georeferencing existing hardcopy maps. The resulting images are georeferenced and then used to digitize and collect geographic information. For example, this includes scanning existing United States Geological Survey (USGS) 1:24,000 quad sheets and using them as the primary source for a GIS.

- Ground surveying geographic information. Ground Global Positioning System (GPS), total stations, and theodolites are commonly used for recording the 3D locations of features. The resulting information is commonly merged into a GIS and associated with existing vector data sets.

- Outsourcing photogrammetric feature collection to service bureaus. Traditional stereo plotters and digital photogrammetry workstations are used to collect highly accurate geographic information such as orthorectified imagery, Digital Terrain Models (DTMs), and 3D vector data sets.

- Remote sensing techniques, such as multi-spectral classification, have traditionally been used for extracting geographic information about the surface of the Earth.

These approaches have been widely accepted within the GIS industry as the primary techniques used to prepare, collect, and maintain the data contained within a GIS; however, GIS professionals throughout the world are beginning to face the following issues:

- The original sources of information used to collect GIS data are becoming obsolete and outdated. The same can be said for the GIS data collected from these sources. How can the data and information in a GIS be updated?

- The accuracy of the source data used to collect GIS data is questionable. For example, how accurate is the 1960 topographic map used to digitize contour lines?

- The amount of time required to prepare and collect GIS data from existing sources of information is great.

- The cost required to prepare and collect GIS data is high. For example, georectifying 500 photographs to map an entire county may take up to three months (which does not include collecting the GIS data). Similarly, digitizing hardcopy maps is time-consuming and costly, not to mention inaccurate.

- Most of the original sources of information used to collect GIS data provide only 2D information. For example, a building is represented with a polygon having only X and Y coordinate information. To create a 3D GIS involves creating DTMs, digitizing contour lines, or surveying the geography of the Earth to obtain 3D coordinate information. Once collected, the 3D information is merged with the 2D GIS to create a 3D GIS. Each approach is ineffective in terms of the time, cost, and accuracy associated with collecting the 3D information for a 2D GIS.

- The cost associated with outsourcing core digital mapping to specialty shops is expensive in both dollars and time. Also, performing regular GIS data updates requires additional outsourcing.

With the advent of image processing and remote sensing systems, the use of imagery for collecting geographic information has become more frequent. Imagery was first used as a reference backdrop for collecting and editing geographic information (including vectors) for a GIS. This imagery included:

- raw photography,

- geocorrected imagery, and

- orthorectified imagery.

Each type of imagery has its advantages and disadvantages, although each is limited to the collection of geographic information in 2D. To accurately represent the Earth and its geography in a GIS, the information must be obtained directly in 3D, regardless of the application. Stereo Analyst provides the solution for directly collecting 3D information from stereo imagery.

Figure 1: Accurate 3D Geographic Information Extracted from Imagery

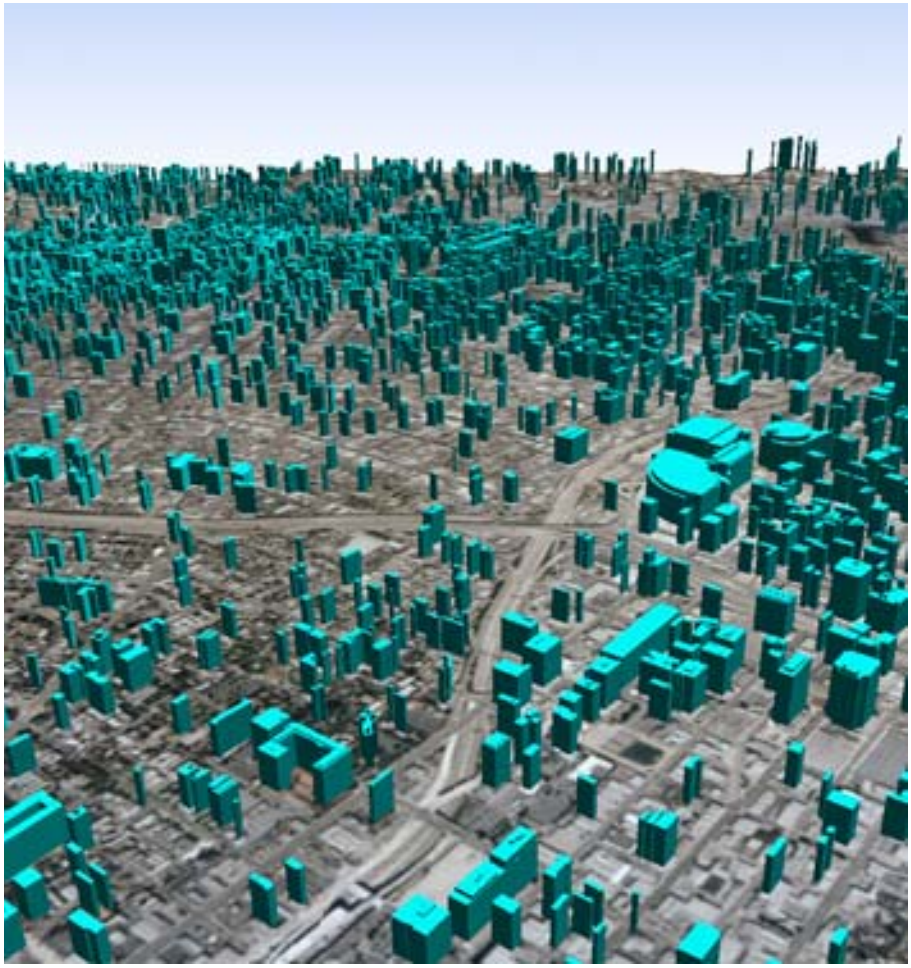


Image Preparation for a GIS

This section describes the various techniques used to prepare imagery for a GIS. By understanding the processes and techniques associated with preparing and extracting geographic information from imagery, we can identify some of the problem issues and provide the complete solution for collecting 3D geographic information.

Using Raw Photography

The following three examples describe the common practices used for the collection of geographic information from raw photographs and imagery. Raw imagery includes scanned hardcopy photography, digital camera imagery, videography, or satellite imagery that has not been processed to establish a geometric relationship between the imagery and the Earth. In this case, the images are not referenced to a geographic projection or coordinate system.

Example 1: Collecting Geographic Information from Hardcopy Photography

Hardcopy photographs are widely used by professionals in several industries as one of the primary sources of geographic information. Foresters, geologists, soil scientists, engineers, environmentalists, and urban planners routinely collect geographic information directly from hardcopy photographs. The hardcopy photographs are commonly used during fieldwork and research. As a result, the hardcopy photographs are a valuable source of information.

For the interpretation of 3D and height information, an adjacent set of photographs is used together with a stereoscope. While in the field, information and measurements collected on the ground are recorded directly onto the hardcopy photographs. Using the hardcopy photographs, information regarding the feature of interest is recorded both spatially (geographic coordinates) and nonspatially (text attribution).

Transferring the geographic information associated with the hardcopy photograph to a GIS involves the following steps:

- Scan the photograph(s).
- Georeference the photograph using known ground control points (GCPs).
- Digitize the features recorded on the photograph(s) using the scanned photographs as a backdrop in a GIS.
- Merge and geolink the recorded tabular data with the collected features in a GIS.

Repeat this procedure for each photograph.

Example 2: Collecting Geographic Information from Hardcopy Photography Using a Transparency

Rather than measure and mark on the photographs directly, a transparency is placed on top of the photographs during feature collection. In this case, a stereoscope is placed over the photographs. Then, a transparency is placed over the photographs. Features and information (spatial and nonspatial) are recorded directly on the transparency. Once the information has been recorded, it is transferred to a GIS. The following steps are commonly used to transfer the information to a GIS:

- Either digitally scan the entire transparency using a desktop scanner, or digitize only the collected features using a digitizing tablet.
- The resulting image or set of digitized features is then georeferenced to the surface of the Earth. The information is georeferenced to an existing vector coverage, rectified map, rectified image, or is georeferenced using GCPs. Once the features have been georeferenced, geographic coordinates (X and Y) are associated with each feature.

- In a GIS, the recorded tabular data (attribution) is entered and merged with the digital set of georeferenced features.

This procedure is repeated for each transparency.

Example 3: Collecting Geographic Information from Scanned Photography

By scanning the raw photography, a digital record of the area of interest becomes available and can be used to collect GIS information. The following steps are commonly used to collect GIS information from scanned photography:

- Georeference the photograph using known GCPs.
- In a GIS, using the scanned photographs as a backdrop, digitize the features recorded on the photograph(s).
- In the GIS, merge and geolink the recorded tabular data with the collected features.

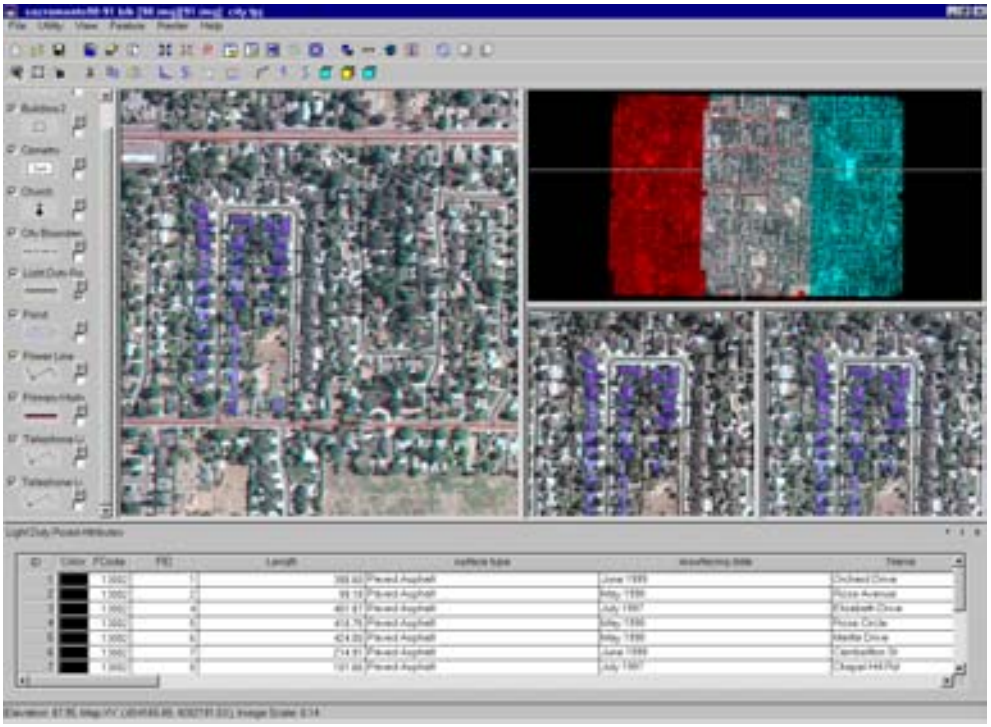
This procedure is repeated for each photograph.

Geoprocessing Techniques

Raw aerial photography and satellite imagery contain large geometric distortion caused by camera or sensor orientation error, terrain relief, Earth curvature, film and scanning distortion, and measurement errors. Measurements made on data sources that have not been rectified for the purpose of collecting geographic information are not reliable.

Geoprocessing techniques warp, stretch, and rectify imagery for use in the collection of 2D geographic information. These techniques include geocorrection and orthorectification, which establish a geometric relationship between the imagery and the ground. The resulting 2D image sources are primarily used as reference backdrops or base image maps on which to digitize geographic information.

Figure 2: Spatial and Nonspatial Information for Local Government Applications



Geocorrection

Conventional techniques of geometric correction (or geocorrection), such as rubber sheeting, are based on approaches that do not directly account for the specific distortion or error sources associated with the imagery. These techniques have been successful in the field of remote sensing and GIS applications, especially when dealing with low resolution and narrow field of view satellite imagery such as Landsat and SPOT. General functions have the advantage of simplicity. They can provide a reasonable geometric modeling alternative when little is known about the geometric nature of the image data.

Problems

Conventional techniques generally process the images one at a time. They cannot provide an integrated solution for multiple images or photographs simultaneously and efficiently. It is very difficult, if not impossible, for conventional techniques to achieve a reasonable accuracy without a great number of GCPs when dealing with high-resolution imagery, images having severe systematic and/or nonsystematic errors, and images covering rough terrain such as mountain areas. Image misalignment is more likely to occur when mosaicking separately rectified images. This misalignment could result in inaccurate geographic information being collected from the rectified images. As a result, the GIS suffers.

Furthermore, it is impossible for geocorrection techniques to extract 3D information from imagery. There is no way for conventional techniques to accurately derive geometric information about the sensor that captured the imagery.

Solution

Techniques used in LPS Project Manager and Stereo Analyst overcome all of these problems by using sophisticated techniques to account for the various types of error in the input data sources. This solution is integrated and accurate. LPS Project Manager can process hundreds of images or photographs with very few GCPs, while at the same time eliminating the misalignment problem associated with creating image mosaics. In short, less time, less money, less manual effort, and more geographic fidelity can be realized using the photogrammetric solution. Stereo Analyst utilizes all of the information processed in LPS Project Manager and accounts for inaccuracies during 3D feature collection, measurement, and interpretation.

Orthorectification

Geocorrected aerial photography and satellite imagery have large geometric distortion that is caused by various systematic and nonsystematic factors. Photogrammetric techniques used in LPS Project Manager eliminate these errors most efficiently, and create the most reliable and accurate imagery from the raw imagery. LPS Project Manager is unique in terms of considering the image-forming geometry by utilizing information between overlapping images, and explicitly dealing with the third dimension, which is elevation.

Orthorectified images, or orthoimages, serve as the ideal information building blocks for collecting 2D geographic information required for a GIS. They can be used as reference image backdrops to maintain or update an existing GIS. Using digitizing tools in a GIS, features can be collected and subsequently attributed to reflect their spatial and nonspatial characteristics. Multiple orthoimages can be mosaicked to form seamless orthoimage base maps.

Problems

Orthorectified images are limited to containing only 2D geometric information. Thus, geographic information collected from orthorectified images is georeferenced to a 2D system. Collecting 3D information directly from orthoimagery is impossible. The accuracy of orthorectified imagery is highly dependent on the accuracy of the DTM used to model the terrain effects caused by the surface of the Earth. The DTM source is an additional source of input during orthorectification. Acquiring a reliable DTM is another costly process. High-resolution DTMs can be purchased at a great expense.

Solution

Stereo Analyst allows for the collection of 3D information; you are no longer limited to only 2D information. Using sophisticated sensor modeling techniques, a DTM is not required as an input source for collecting accurate 3D geographic information. As a result, the accuracy of the geographic information collected in Stereo Analyst is higher. There is no need to spend countless hours collecting DTMs and merging them with your GIS.

Traditional Approaches

Unfortunately, 3D geographic information cannot be directly measured or interpreted from geocorrected images, orthorectified images, raw photography, or scanned topographic or cartographic maps. The resulting geographic information collected from these sources is limited to 2D only, which consists of X and Y georeferenced coordinates. In order to collect the additional Z (height) information, additional processing is required. The following examples explain how 3D information is normally collected for a GIS.

Example 1

The first example involves digitizing hardcopy cartographic and topographic maps and attributing the elevation of contour lines. Subsequent interpolation of contour lines is required to create a DTM. The digitization of these sources includes either scanning the entire map or digitizing individual features from the maps.

Problem

The accuracy and reliability of the topographic or cartographic map cannot be guaranteed. As a result, an error in the map is introduced into your GIS. Additionally, the magnitude of error is increased due to the questionable scanning or digitization process.

Example 2

The second example involves merging existing DTMs with geographic information contained in a GIS.

Problem

Where did the DTMs come from? How accurate are the DTMs? If the original source of the DTM is unknown, then the quality of the DTM is also unknown. As a result, any inaccuracies are translated into your GIS.

Can you easily edit and modify problem areas in the DTM? Many times, the problem areas in the DTM cannot be edited, since the original imagery used to create the DTM is not available, or the accompanying software is not available.

Example 3

This example involves using ground surveying techniques such as ground GPS, total stations, levels, and theodolites to capture angles, distances, slopes, and height information. You are then required to geolink and merge the land surveying information within the geographic information contained in the GIS.

Problem

Ground surveying techniques are accurate, but are labor intensive, costly, and time-consuming—even with new GPS technology. Also, additional work is required by you to merge and link the 3D information with the GIS. The process of geolinking and merging the 3D information with the GIS may introduce additional errors to your GIS.

Example 4

The next example involves automated digital elevation model (DEM) extraction. Using two overlapping images, a regular grid of elevation points or a dispersed number of 3D mass points (that is, triangulated irregular network [TIN]) can be automatically extracted from imagery. You are then required to merge the resulting DTM with the geographic information contained in the GIS.

Problem

You are restricted to the collection of point elevation information. For example, using this approach, the slope of a line or the 3D position of a road cannot be extracted. Similarly, a polygon of a building cannot be directly collected. Many times post-editing is required to ensure the accuracy and reliability of the elevation sources. Automated DEM extraction consists of just one required step to create the elevation or 3D information source. Additional steps of DTM interpolation and editing are required, not to mention the additional process of merging the information with your GIS.

Example 5

This example involves outsourcing photogrammetric feature collection and data capture to photogrammetric service bureaus and production shops. Using traditional stereoplotters and digital photogrammetric workstations, 3D geographic information is collected from stereo models. The 3D geographic information may include DTMs, 3D features, and spatial and nonspatial attribution ready for input in your GIS database.

Problem

Using these sophisticated and advanced tools, the procedures required for collecting 3D geographic information become costly. The use of such equipment is generally limited to highly skilled photogrammetrists.

Geographic Imaging

To preserve the investment made in a GIS, a new approach is required for the collection and maintenance of geographic data and information in a GIS. The approach must provide the ability to:

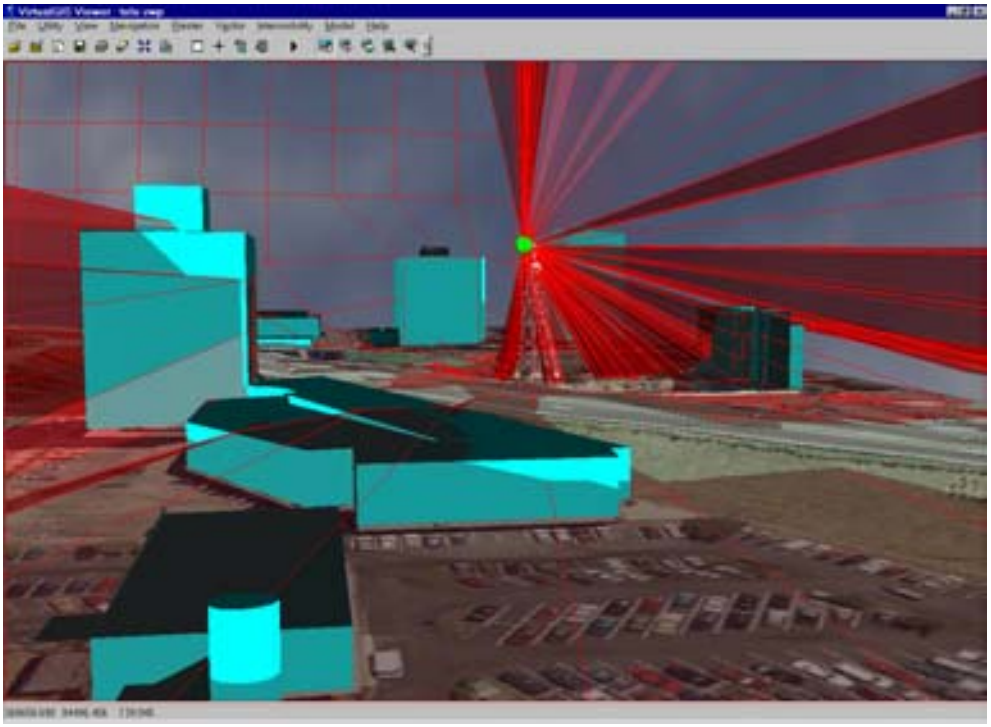
- Access and use readily available, up-to-date sources of information for the collection of GIS data and information.
- Accurately collect both 2D and 3D GIS data from a variety of sources.

- Minimize the time associated with preparing, collecting, and editing GIS data.
- Minimize the cost associated with preparing, collecting, and editing GIS data.
- Collect 3D GIS data directly from raw source data without having to perform additional preparation tasks.
- Integrate new sources of imagery easily for the maintenance and update of data and information in a GIS.

The only solution that can address all of the aforementioned issues involves the use of imagery. Imagery provides an up-to-date, highly accurate representation of the Earth and its associated geography. Various types of imagery can be used, including aerial photography, satellite imagery, digital camera imagery, videography, and 35 mm photography. With the advent of high resolution satellite imagery, GIS data can be updated accurately and immediately.

Synthesizing the concepts associated with photogrammetry, remote sensing, GIS, and 3D visualization introduces a new paradigm for the future of digital mapping—one that integrates the respective technologies into a single, comprehensive environment for the accurate preparation of imagery and the collection and extraction of 3D GIS data and geographic information. This paradigm is referred to as 3D geographic imaging. 3D geographic imaging techniques will be used for building the 3D GIS of the future.

Figure 3: 3D Information for GIS Analysis



3D geographic imaging is the process associated with transforming imagery into GIS data or, more importantly, information. 3D geographic imaging prevents the inclusion of inaccurate or outdated information into a GIS. Sophisticated and automated techniques are used to ensure that highly accurate 3D GIS data can be collected and maintained using imagery. 3D geographic imaging techniques use a direct approach to collecting accurate 3D geographic information, thereby eliminating the need to digitize from a secondary data source like hardcopy or digital maps. These new tools significantly improve the reliability of GIS data and reduce the steps and time associated with populating a GIS with accurate information.

The backbone of 3D geographic imaging is digital photogrammetry. Photogrammetry has established itself as the main technique for obtaining accurate 3D information from photography and imagery. Traditional photogrammetry uses specialized and expensive stereoscopic plotting equipment. Digital photogrammetry uses computer-based systems to process digital photography or imagery. With the advent of digital photogrammetry, many of the processes associated with photogrammetry have been automated.

Over the last several decades, the idea of integrating photogrammetry and GIS has intimidated many people. The cost and learning curve associated with incorporating the technology into a GIS has created a chasm between photogrammetry and GIS data collection, production, and maintenance. As a result, many GIS professionals have resorted to outsourcing their digital mapping projects to specialty photogrammetric production shops. Advancements in softcopy photogrammetry, or digital photogrammetry, have broken down these barriers. Digital photogrammetric techniques bridge the gap between GIS data collection and photogrammetry. This is made possible through the automated processes associated with digital photogrammetry.

From Imagery to a 3D GIS

Transforming imagery into 3D GIS data involves several processes commonly associated with digital photogrammetry. The data and information required for building and maintaining a 3D GIS includes orthorectified imagery, DTMs, 3D features, and the nonspatial attribute information associated with the 3D features. Through various processing steps, 3D GIS data can be automatically extracted and collected from imagery.

Imagery Types

Digital photogrammetric techniques are not restricted as to the type of photography and imagery that can be used to collect accurate GIS data. Traditional applications of photogrammetry use aerial photography (commonly 9 x 9 inches in size). Technological breakthroughs in photogrammetry now allow for the use of satellite imagery, digital camera imagery, videography, and 35 mm camera photography. In order to use hardcopy photographs in a digital photogrammetric system, the photographs must be scanned or digitized. Depending on the digital mapping project, various scanners can be used to digitize photography. For highly accurate mapping projects, calibrated photogrammetric scanners must be used to scan the photography to very high precisions. If high-end micron accuracy is not required, more affordable desktop scanners can be used.

Conventional photogrammetric applications, such as topographic mapping and contour line collection, use aerial photography. With the advent of digital photogrammetric systems, applications have been extended to include the processing of oblique and terrestrial photography and imagery.

Given the use of computer hardware and software for photogrammetric processing, various image file formats can be used. These include TIF, JPEG, GIF, Raw and Generic Binary, and Compressed imagery, along with various software vendor-specific file formats.

Workflow

The workflow associated with creating 3D GIS data is linear. The hierarchy of processes involved with creating highly accurate geographic information can be broken down into several steps, which include:

- Define the sensor model.
- Measure GCPs.
- Collect tie points (automated).
- Perform bundle block adjustment (that is, aerial triangulation).
- Extract DTMs (automated).
- Orthorectify the images.
- Collect and attribute 3D features.

This workflow is generic and does not necessarily need to be repeated for every GIS data collection and maintenance project. For example, a bundle block adjustment does not need to be performed every time a 3D feature is collected from imagery.

Defining the Sensor Model

A sensor model describes the properties and characteristics associated with the camera or sensor used to capture photography and imagery. Since digital photogrammetry allows for the accurate collection of 3D information from imagery, all of the characteristics associated with the camera/sensor, the image, and the ground must be known and determined. Photogrammetric sensor modeling techniques define the specific information associated with a camera/sensor as it existed when the imagery was captured. This information includes both internal and external sensor model information.

Internal sensor model information describes the internal geometry of the sensor as it exists when the imagery is captured. For aerial photographs, this includes the focal length, lens distortion, fiducial mark coordinates, and so forth. This information is normally provided to you in the form of a calibration report. For digital cameras, this includes focal length and the pixel size of the charge-coupled device (CCD) sensor. For satellites, this includes internal satellite information such as the pixel size, the number of columns in the sensor, and so forth. If some of the internal sensor model information is not available (for example, in the case of historical photography), sophisticated techniques can be used to determine the internal sensor model information. This technique is normally associated with performing a bundle block adjustment and is referred to as self-calibration.

External sensor model information describes the exact position and orientation of each image as they existed when the imagery was collected. The position is defined using 3D coordinates. The orientation of an image at the time of capture is defined in terms of rotation about three axes: Omega (ω), Phi (φ), and Kappa (κ) (see Figure 16 for an illustration of the three axes). Over the last several years, it has been common practice to collect airborne GPS and inertial navigation system (INS) information at the time of image collection. If this information is available, the external sensor model information can be directly input for use in subsequent photogrammetric processing. If external sensor model information is not available, most photogrammetric systems can determine the exact position and orientation of each image in a project using the bundle block adjustment approach.

Measuring GCPs

Unlike traditional georectification techniques, GCPs in digital photogrammetry have three coordinates: X, Y, and Z. The image locations of 3D GCPs are measured across multiple images. GCPs can be collected from existing vector files, orthorectified images, DTMs, and scanned topographic and cartographic maps.

GCPs serve a vital role in photogrammetry since they are crucial to establishing an accurate geometric relationship between the images in a project, the sensor model, and the ground. This relationship is established using the bundle block adjustment approach. Once established, 3D GIS data can be accurately collected from imagery. The number of GCPs varies from project to project. For example, if a strip of five photographs is being processed, a minimum of three GCPs can be used. Optimally, five or six GCPs are distributed throughout the overlap areas of the five photographs.

Automated Tie Point Collection

To prevent misaligned orthophoto mosaics and to ensure accurate DTMs and 3D features, tie points are commonly measured within the overlap areas of multiple images. A tie point is a point whose ground coordinates are not known, but is visually recognizable in the overlap area between multiple images.

Tie point collection is the process of identifying and measuring tie points across multiple overlapping images. Tie points are used to join the images in a project so that they are positioned correctly relative to one another. Traditionally, tie points have been collected manually, two images at a time. With the advent of new, sophisticated, and automated techniques, tie points are now collected automatically, saving you time and money in the preparation of 3D GIS data. Digital image matching techniques are used to automatically identify and measure tie points across multiple overlapping images.

Bundle Block Adjustment

Once GCPs and tie points have been collected, the process of establishing an accurate relationship between the images in a project, the camera/sensor, and the ground can be performed. This process is referred to as bundle block adjustment.

Since it determines most of the necessary information that is required to create orthophotos, DTMs, DSMs, and 3D features, bundle block adjustment is an essential part of processing. The components needed to perform a bundle block adjustment may include the internal sensor model information, external sensor model information, the 3D coordinates of tie points, and additional parameters characterizing the sensor model. This output is commonly provided with detailed statistical reports outlining the accuracy and precision of the derived data. For example, if the accuracy of the external sensor model information is known, then the accuracy of 3D GIS data collected from this source data can be determined.

You can learn more about the bundle block adjustment method in "Photogrammetry".

Automated DTM Extraction

Rather than manually collecting individual 3D point positions with a GPS or using direct 3D measurements on imagery, automated techniques extract 3D representations of the surface of the Earth using the overlap areas of two images. This is referred to as automated DTM extraction. Digital image matching (that is, auto-correlation) techniques are used to automatically identify and measure the positions of common ground points appearing within the overlap area of two adjacent images.

Using sensor model information determined from bundle block adjustment, the image positions of the ground points are transformed into 3D point positions. Once the automated DTM extraction process has been completed, a series of evenly distributed 3D mass points is located within the geographic area of interest. The 3D mass points can then be interpolated to create a TIN or a raster DEM. DTMs form the basis of many GIS applications including watershed analysis, line of sight (LOS) analysis, road and highway design, and geological bedform discrimination. DTMs are also vital for the creation of orthorectified images.

LPS Automatic Terrain Extraction (ATE) can automatically extract DTMs from imagery.

Orthorectification

Orthorectification is the process of removing geometric errors inherent within photography and imagery. Using sensor model information and a DTM, errors associated with sensor orientation, topographic relief displacement, Earth curvature, and other systematic errors are removed to create accurate imagery for use in a GIS. Measurements and geographic information collected from an orthorectified image represent the corresponding measurements as if they were taken on the surface of the Earth. Orthorectified images serve as the image backdrops for displaying and editing vector layers.

3D Feature Collection and Attribution

3D GIS data and information can be collected from what is referred to as a DSM. Based on sensor model information, two overlapping images comprising a DSM can be aligned, leveled, and scaled to produce a 3D stereo effect when viewed with appropriate stereo viewing hardware.

A DSM allows for the interpretation, collection, and visualization of 3D geographic information from imagery. The DSM is used as the primary data source for the collection of 3D GIS data. 3D GIS allows for the direct collection of 3D geographic information from a DSM using a 3D floating cursor. Thus, additional elevation data is not required. True 3D information is collected directly from imagery.

During the collection of 3D GIS data, a 3D floating cursor displays within the DSM while viewing the imagery in stereo. The 3D floating cursor commonly floats above, below, or rests on the surface of the Earth or object of interest. To ensure the accuracy of 3D GIS data, the height of the floating cursor is adjusted so that it rests on the feature being collected. When the 3D floating cursor rests on the ground or feature, it can be accurately collected.

Figure 4: Accurate 3D Buildings Extracted using Stereo Analyst

Automated terrain following cursor capabilities can be used to automatically place the 3D floating cursor on the ground so that you do not have to manually adjust the height of the cursor every time a feature is collected. For example, the collection of a feature in 3D is as simple as using the automated terrain following cursor with stream mode digitizing activated. In this scenario, you simply hold the left mouse button and trace the cursor over the feature of interest. The resulting output is 3D GIS data.

For the update and maintenance of a GIS, existing vector layers are commonly superimposed on a DSM and then reshaped to their accurate real-world positions. 2D vector layers can be transformed into 3D geographic information using most 3D geographic imaging systems. During the collection of 3D GIS data, the attribute information associated with a vector layer can be edited. Attribute tables can be displayed with the DSM during the collection of 3D GIS data.

You can work with attribute tables in "Collecting and Editing 3D GIS Data".

Interpreting the DSM during the capture of 3D GIS data allows for the collection, maintenance, and input of nonspatial information such as the type of tree and zoning designation in an urban area. Automated attribution techniques simultaneously populate a GIS during the collection of 3D features with such data as area, perimeter, and elevation. Additional qualitative and quantitative attribution information associated with a feature can be input during the collection process.

3D GIS Data from Imagery

The products resulting from using 3D geographic imaging techniques include orthorectified imagery, DTMs, DSMs, 3D features, 3D measurements, and attribute information associated with a feature. Using these primary sources of geographic information, additional GIS data can be collected, updated, and edited. An increasing trend in the geocommunity involves the use of 3D data in GIS spatial modeling and analysis.

3D GIS Applications

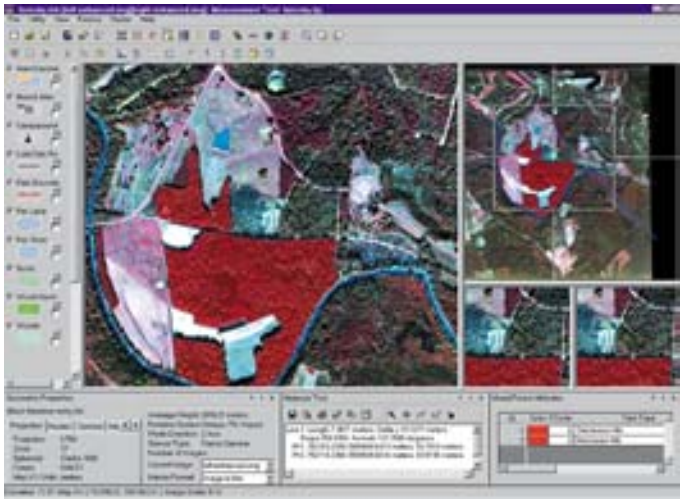
The 3D GIS data collected using 3D geographic imaging can be used for spatial modeling, GIS analysis, and 3D visualization and simulation applications. The following examples illustrate how 3D geographic imaging techniques can be used for applications in forestry, geology, local government, water resource management, and telecommunications.

Forestry

For forest inventory applications, an interpreter identifies different tree stands from one another based on height, density (crown cover), species composition, and various modifiers such as slope, type of topography, and soil characteristics. Using a DSM, a forest stand can be identified and measured as a 3D polygon. 3D geographic imaging techniques are used to provide the GIS data required to determine the volume of a stand. This includes using a DSM to collect tree stand height, tree-crown diameter, density, and area.

Using 3D DSMs with high resolution imagery, various tree species can be identified based on height, color, texture, and crown shape. Appropriate feature codes can be directly placed and georeferenced to delineate forest stand polygons. The feature code information is directly indexed to a GIS for subsequent analysis and modeling.

Figure 5: Use of 3D Geographic Imaging Techniques in Forestry



Based on the information collected from DSMs, forestry companies use the 3D information in a GIS to determine the amount of marketable timber located within a given plot of land, the amount of timber lost due to fire or harvesting, and where foreseeable problems may arise due to harvesting in unsuitable geographic areas.

Geology

Prior to beginning expensive exploration projects, geologists take an inventory of a geographic area using imagery as the primary source of information. DSMs are frequently used to improve the quantity and quality of geologic information that can be interpreted from imagery. Changes in topographic relief are often used in lithological mapping applications since these changes, together with the geomorphologic characteristics of the terrain, are controlled by the underlying geology. DSMs are utilized for lithologic discrimination and geologic structure identification. Dip angles can be recorded directly on a DSM in order to assist in identifying underlying geologic structures. By digitizing and collecting geologic information using a DSM, the resulting geologic map is in a form and projection that can be immediately used in a GIS. Together with multispectral information, high resolution imagery produces a wealth of highly accurate 3D information for the geologist.

Local Government

In order to formulate social, economic, and cultural policies, GIS sources must be timely, accurate, and cost-effective. High resolution imagery provides the primary data source for obtaining up-to-date geographic information for local government applications. Existing GIS vector layers are commonly superimposed onto DSMs for immediate update and maintenance.

DSMs created from high resolution imagery are used for the following applications:

- Land use/land cover mapping involves the identification and categorization of urban and rural land use and land cover. Using DSMs, 3D topographic information, slope, vegetation type, soil characteristics, underlying geological information, and infrastructure information can be collected as 3D vectors.

- Land use suitability evaluation usually requires soil mapping. DSMs allow for the accurate interpretation and collection of soil type, slope, soil suitability, soil moisture, soil texture, and surface roughness. As a result, the suitability of a given infrastructure development can be determined.

- Population estimation requires accurate 3D high resolution imagery for determining the number of units for various household types. The height of buildings is important.

- Housing quality studies require environmental information derived from DSMs including house size, lot size, building density, street width and condition, driveway presence/absence, vegetation quality, and proximity to other land use types.

- Site selection applications require the identification and inventory of various geographic information. Site selection applications include transportation route selection, sanitary landfill site selection, power plant siting, and transmission line location. Each application requires accurate 3D topographic representations, geologic inventory, soils inventory, land use, vegetation inventory, and so forth.

- Urban change detection studies use photography collected from various time periods for analyzing the extent of urban growth. Land use and land cover information is categorized for each time period, and subsequently compared to determine the extent and nature of land use/land cover change.

Water Resource Management

DSMs are a necessary asset for monitoring the quality, quantity, and geographic distribution of water. The 3D information collected from DSMs is used to provide descriptive and quantitative watershed information for a GIS. Various watershed characteristics can be derived from DSMs including terrain type and extent, surficial geology, river or stream valley characteristics, river channel extent, river bed topography, and terraces. Individual river channel reaches can be delineated in 3D, providing an accurate representation of a river.

Rather than manually survey 3D point information in the field, highly accurate 3D information can be collected from DSMs to estimate sediment storage, river channel width, and valley flat width. Using historical photography, 3D measurements of a river channel and bank can be used to estimate rates of bank erosion/deposition, identify channel change, and describe channel evolution/disturbance.

Telecommunications

The growing telecommunications industry requires accurate 3D information for various applications associated with wireless telecommunications. 3D geographic representations of buildings are required for radio engineering analysis and LOS between building rooftops in urban and rural environments. Accurate 3D building information is required to properly perform the analysis. Once the 3D data has been collected, it can be used for radio coverage planning, system propagation prediction, plotting and analysis, network optimization, antenna siting, and point-to-point inspection for signal validation.

Next

Next, you can learn about the principles of photogrammetry, and how Stereo Analyst uses those principles to provide accurate results in your GIS.

Photogrammetry

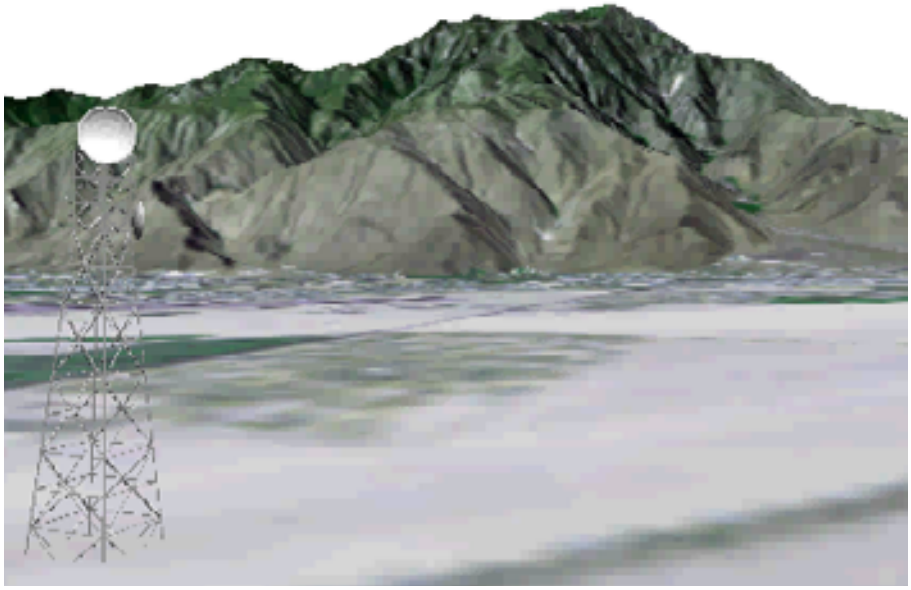
Introduction

This chapter introduces you to the general principles that form the foundation of digital mapping and photogrammetry.

Principles of Photogrammetry

Photogrammetric principles are used to extract topographic information from aerial photographs and imagery. Figure 6 illustrates rugged topography. This type of topography can be viewed in 3D using Stereo Analyst.

Figure 6: Topography



What is Photogrammetry?

Photogrammetry is the "art, science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring and interpreting photographic images and patterns of electromagnetic radiant imagery and other phenomena" (American Society of Photogrammetry 1980).

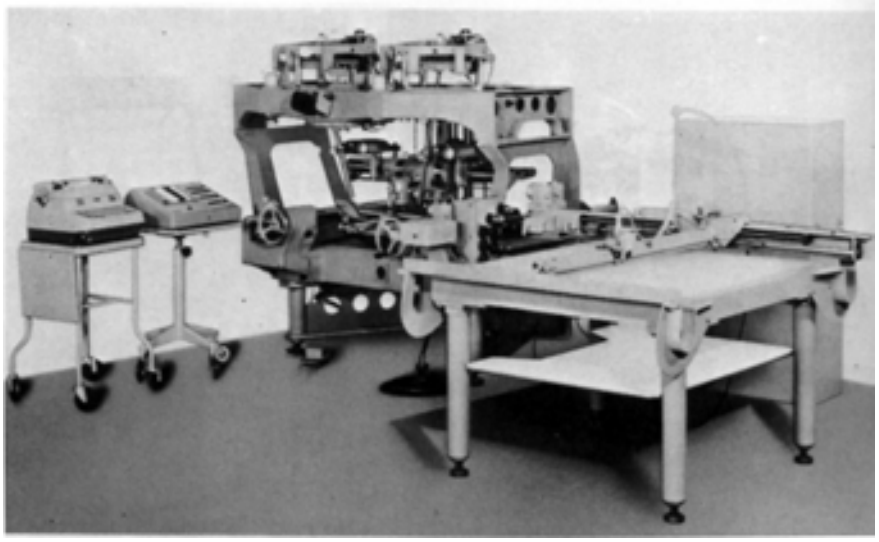
Photogrammetry was invented in 1851 by Laussedat, and has continued to develop over the last century plus. Over time, the development of photogrammetry has passed through the phases of plane table photogrammetry, analog photogrammetry, analytical photogrammetry, and has now entered the phase of digital photogrammetry (Konecny 1994).

The traditional, and largest, application of photogrammetry is to extract topographic and planimetric information (for example, topographic maps) from aerial images. However, photogrammetric techniques have also been applied to process satellite images and close-range images to acquire topographic or nontopographic information of photographed objects. Topographic information includes spot height information, contour lines, and elevation data. Planimetric information includes the geographic location of buildings, roads, rivers, etc.

Prior to the invention of the airplane, photographs taken on the ground were used to extract the relationship between objects using geometric principles. This was during the phase of plane table photogrammetry.

In analog photogrammetry, starting with stereo measurement in 1901, optical or mechanical instruments, such as the analog plotter, were used to reconstruct 3D geometry from two overlapping photographs. The main product during this phase was topographic maps.

Figure 7: Analog Stereo Plotter

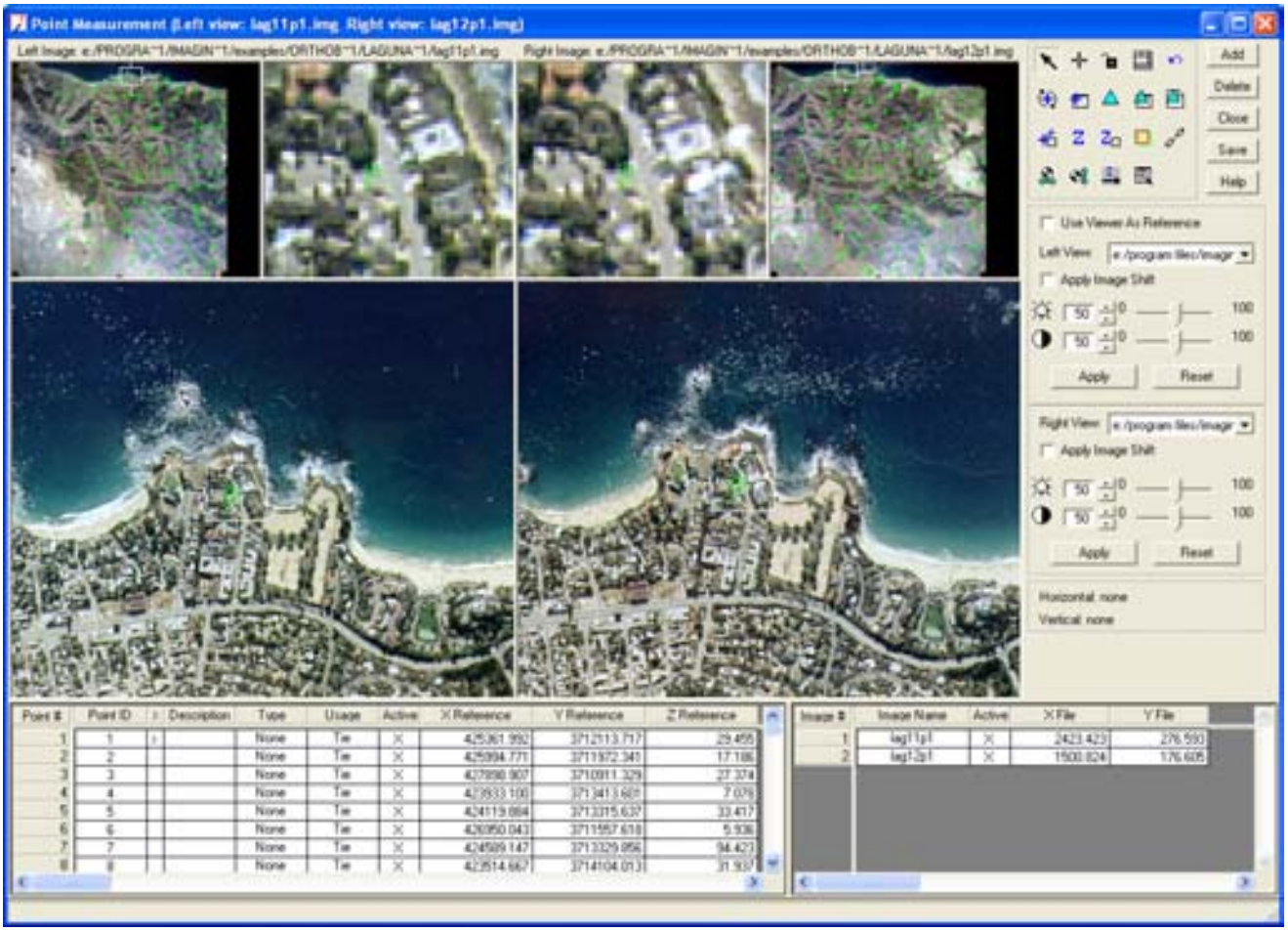


In analytical photogrammetry, the computer replaces some expensive optical and mechanical components. The resulting devices were analog/digital hybrids. Analytical aerotriangulation, analytical plotters, and orthophoto projectors were the main developments during this phase. Outputs of analytical photogrammetry can be topographic maps, but can also be digital products, such as digital maps and DEMs.

Digital photogrammetry is photogrammetry applied to digital images that are stored and processed on a computer. Digital images can be scanned from photographs or directly captured by digital cameras. Many photogrammetric tasks can be highly automated in digital photogrammetry (for example, automatic DEM extraction and digital orthophoto generation). Digital photogrammetry is sometimes called softcopy photogrammetry. The output products are in digital form, such as digital maps, DEMs, and digital orthophotos saved on computer storage media. Therefore, they can be easily stored, managed, and used by you. With the development of digital photogrammetry, photogrammetric techniques are more closely integrated into remote sensing and GIS.

Digital photogrammetric systems employ sophisticated software to automate the tasks associated with conventional photogrammetry, thereby minimizing the extent of manual interaction required to perform photogrammetric operations. One such application is LPS Project Manager, the interface of which is shown in Figure 8.

Figure 8: LPS Project Manager Point Measurement Tool Interface



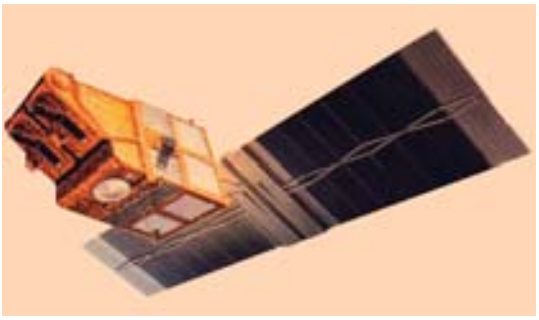
The Leica Photogrammetry Suite Project Manager is capable of automating photogrammetric tasks using many different types of photographs and images.

Photogrammetry can be used to measure and interpret information from hardcopy photographs or images. Sometimes the process of measuring information from photography and satellite imagery is considered metric photogrammetry. Interpreting information from photography and imagery is considered interpretative photogrammetry, such as identifying and discriminating between various tree types (Wolf 1983).

Types of Photographs and Images

The types of photographs and images that can be processed include aerial, terrestrial, close-range, and oblique. Aerial or vertical (near vertical) photographs and images are taken from a high vantage point above the surface of the Earth. The camera axis of aerial or vertical photography is commonly directed vertically (or near vertically) down. Aerial photographs and images are commonly used for topographic and planimetric mapping projects and are commonly captured from an aircraft or satellite. Figure 9 illustrates a satellite. Satellites use onboard cameras to collect high resolution images of the surface of the Earth.

Figure 9: Satellite



Terrestrial or ground-based photographs and images are taken with the camera stationed on or close to the surface of the Earth. Terrestrial and close-range photographs and images are commonly used for applications involved with archeology, geomorphology, civil engineering, architecture, industry, etc.

Oblique photographs and images are similar to aerial photographs and images, except the camera axis is intentionally inclined at an angle with the vertical. Oblique photographs and images are commonly used for reconnaissance and corridor mapping applications.

Digital photogrammetric systems use digitized photographs or digital images as the primary source of input. Digital imagery can be obtained from various sources. These include:

- digitizing existing hardcopy photographs,

- using digital cameras to record imagery, and
- using sensors onboard satellites such as Landsat, SPOT, and IRS to record imagery.

This document uses the term imagery in reference to photography and imagery obtained from various sources. This includes aerial and terrestrial photography, digital and video camera imagery, 35 mm photography, medium to large format photography, scanned photography, and satellite imagery.

Why use Photogrammetry?

Raw aerial photography and satellite imagery have large geometric distortion that is caused by various systematic and nonsystematic factors. Photogrammetric processes eliminate these errors most efficiently, and provide the most reliable solution for collecting geographic information from raw imagery. Photogrammetry is unique in terms of considering the image-forming geometry, utilizing information between overlapping images, and explicitly dealing with the third dimension: elevation.

Photogrammetric techniques allow for the collection of the following geographic data:

- 3D GIS vectors
- DTMs, which include TINs and DEMs
- orthorectified images
- DSMs
- topographic contours

In essence, photogrammetry produces accurate and precise geographic information from a wide range of photographs and images. Any measurement taken on a photogrammetrically processed photograph or image reflects a measurement taken on the ground. Rather than constantly go to the field to measure distances, areas, angles, and point positions on the surface of the Earth, photogrammetric tools allow for the accurate collection of information from imagery. Photogrammetric approaches for collecting geographic information save time and money, and maintain the highest accuracies.

Image and Data Acquisition

During photographic or image collection, overlapping images are exposed along a direction of flight. Most photogrammetric applications involve the use of overlapping images. By using more than one image, the geometry associated with the camera/sensor, image, and ground can be defined to greater accuracies.

During the collection of imagery, each point in the flight path at which the camera exposes the film, or the sensor captures the imagery, is called an exposure station (see Figure 10 and Figure 11).

Figure 10: Exposure Station

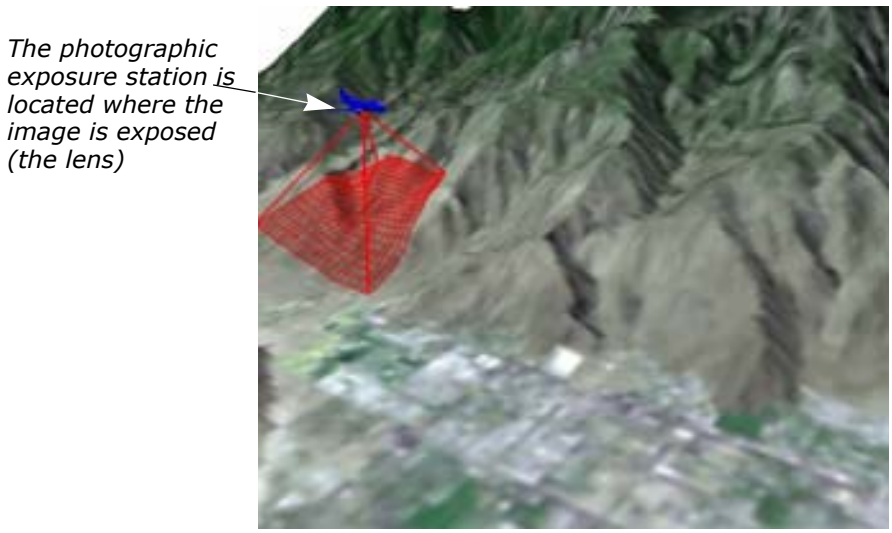
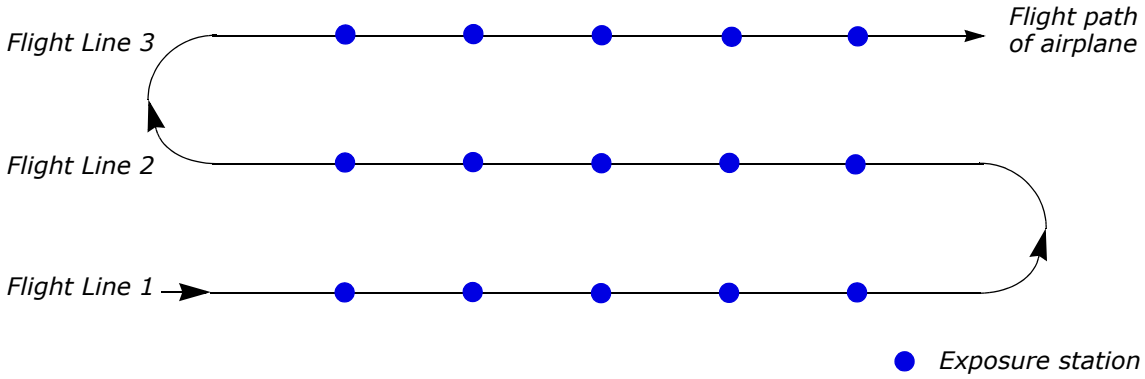


Figure 11: Exposure Stations Along a Flight Path



Each photograph or image that is exposed has a corresponding image scale (SI) associated with it. The SI expresses the average ratio between a distance in the image and the same distance on the ground. It is computed as focal length divided by the flying height above the mean ground elevation. For example, with a flying height of 1000 m and a focal length of 15 cm, the SI would be 1:6667.

NOTE: The flying height above ground is used to determine SI, versus the altitude above sea level.

A strip of photographs consists of images captured along a flight line, normally with an overlap of 60%. All photos in the strip are assumed to be taken at approximately the same flying height and with a constant distance between exposure stations. Camera tilt relative to the vertical is assumed to be minimal.

The photographs from several flight paths can be combined to form a block of photographs. A block of photographs consists of a number of parallel strips, normally with a sidelap of 20-30%.

A regular block of photos is commonly a rectangular block in which the number of photos in each strip is the same. Figure 12 shows a block of 5 x 2 photographs. In cases where a nonlinear feature is being mapped (for example, a river), photographic blocks are frequently irregular. Figure 13 illustrates two overlapping images.

Figure 12: A Regular Rectangular Block of Aerial Photos

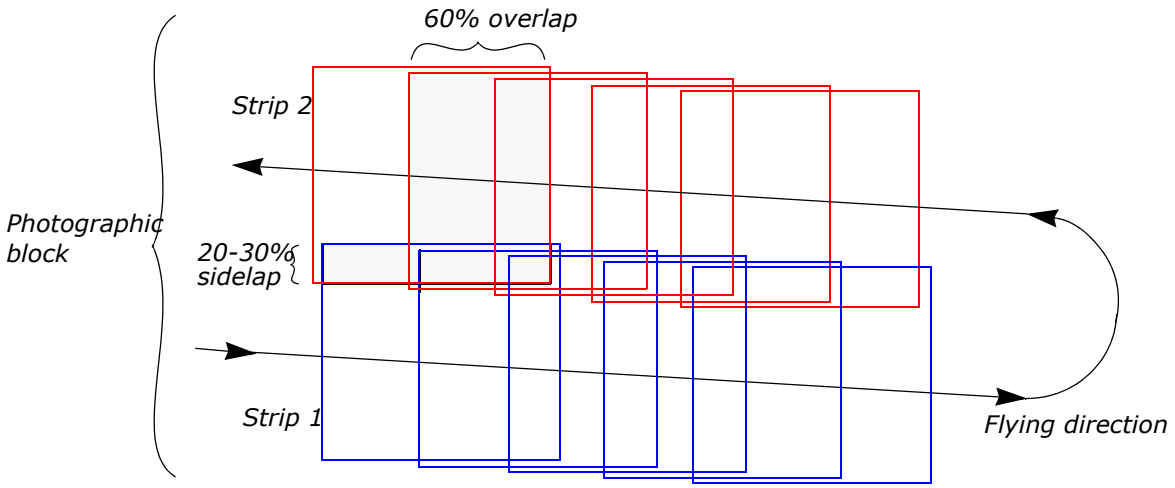
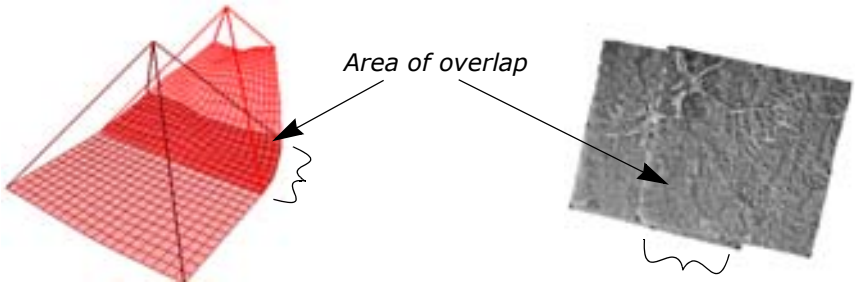


Figure 13: Overlapping Images



Scanning Aerial Photography

Photogrammetric Scanners

Photogrammetric scanners are special devices capable of high image quality and excellent positional accuracy. Use of this type of scanner results in geometric accuracies similar to traditional analog and analytical photogrammetric instruments. These scanners are necessary for digital photogrammetric applications that have high accuracy requirements.

These units usually scan only film because film is superior to paper, both in terms of image detail and geometry. These units usually have a Root Mean Square Error (RMSE) positional accuracy of 4 microns or less, and are capable of scanning at a maximum resolution of 5 to 10 microns (5 microns is equivalent to approximately 5,000 pixels per inch).

The required pixel resolution varies depending on the application. Aerial triangulation and feature collection applications often scan in the 10- to 15-micron range. Orthophoto applications often use 15- to 30-micron pixels. Color film is less sharp than panchromatic, therefore, color ortho applications often use 20- to 40-micron pixels. The optimum scanning resolution also depends on the desired photogrammetric output accuracy. Scanning at higher resolutions provides data with higher accuracy.

Desktop Scanners

Desktop scanners are general purpose devices. They lack the image detail and geometric accuracy of photogrammetric-quality units, but they are much less expensive. When using a desktop scanner, you should make sure that the active area is at least 9 x 9 inches, which enables you to capture the entire photo frame.

Desktop scanners are appropriate for less rigorous uses, such as digital photogrammetry in support of GIS or remote sensing applications. Calibrating these units improves geometric accuracy, but the results are still inferior to photogrammetric units. The image correlation techniques that are necessary for automatic tie point collection and elevation extraction are often sensitive to scan quality. Therefore, errors attributable to scanning errors can be introduced into GIS data that is photogrammetrically derived.

Scanning Resolutions

One of the primary factors contributing to the overall accuracy of 3D feature collection is the resolution of the imagery being used. Image resolution is commonly determined by the scanning resolution (if film photography is being used), or by the pixel resolution of the sensor.

In order to optimize the attainable accuracy of GIS data collection, the scanning resolution must be considered. The appropriate scanning resolution is determined by balancing the accuracy requirements versus the size of the mapping project and the time required to process the project.

Table 4 lists the scanning resolutions associated with various scales of photography and image file size.

Table 4: Scanning Resolutions

	12 microns (2117 dpi)	16 microns (1588 dpi)	25 microns (1016 dpi)	50 microns (508 dpi)	85 microns (300 dpi)
Photo Scale 1 to	**Ground Coverage (meters)**	**Ground Coverage (meters)**	**Ground Coverage (meters)**	**Ground Coverage (meters)**	**Ground Coverage (meters)**
1800	0.0216	0.0288	0.045	0.09	0.153
2400	0.0288	0.0384	0.06	0.12	0.204
3000	0.036	0.048	0.075	0.15	0.255
3600	0.0432	0.0576	0.09	0.18	0.306
4200	0.0504	0.0672	0.105	0.21	0.357
4800	0.0576	0.0768	0.12	0.24	0.408
5400	0.0648	0.0864	0.135	0.27	0.459
6000	0.072	0.096	0.15	0.3	0.51
6600	0.0792	0.1056	0.165	0.33	0.561
7200	0.0864	0.1152	0.18	0.36	0.612
7800	0.0936	0.1248	0.195	0.39	0.663
8400	0.1008	0.1344	0.21	0.42	0.714
9000	0.108	0.144	0.225	0.45	0.765
9600	0.1152	0.1536	0.24	0.48	0.816
10800	0.1296	0.1728	0.27	0.54	0.918
12000	0.144	0.192	0.3	0.6	1.02
15000	0.18	0.24	0.375	0.75	1.275
18000	0.216	0.288	0.45	0.9	1.53
24000	0.288	0.384	0.6	1.2	2.04
30000	0.36	0.48	0.75	1.5	2.55
40000	0.48	0.64	1	2	3.4
50000	0.6	0.8	1.25	2.5	4.25
60000	0.72	0.96	1.5	3	5.1
B/W File Size (MB)	363	204	84	21	7
Color File Size (MB)	1089	612	252	63	21

The Ground Coverage column refers to the ground coverage per pixel. Thus, a 1:40000 scale black and white photograph scanned at 25 microns (1016 dpi) has a ground coverage per pixel of 1 m x 1 m. The resulting file size is approximately 85 MB, assuming a square 9 x 9 inch photograph.

Coordinate Systems

Conceptually, photogrammetry involves establishing the relationship between the camera or sensor used to capture the imagery, the imagery itself, and the ground. In order to understand and define this relationship, each of the three variables associated with the relationship must be defined with respect to a coordinate space and coordinate system.

Pixel Coordinate System

The file coordinates of a digital image are defined in a pixel coordinate system. A pixel coordinate system is usually a coordinate system with its origin in the upper-left corner of the image, the x-axis pointing to the right, the y-axis pointing downward, and the units in pixels, as shown by axes *c* and *r* in Figure 14. These file coordinates (*c, r*) can also be thought of as the pixel column and row number, respectively.

Figure 14: Pixel Coordinates and Image Coordinates

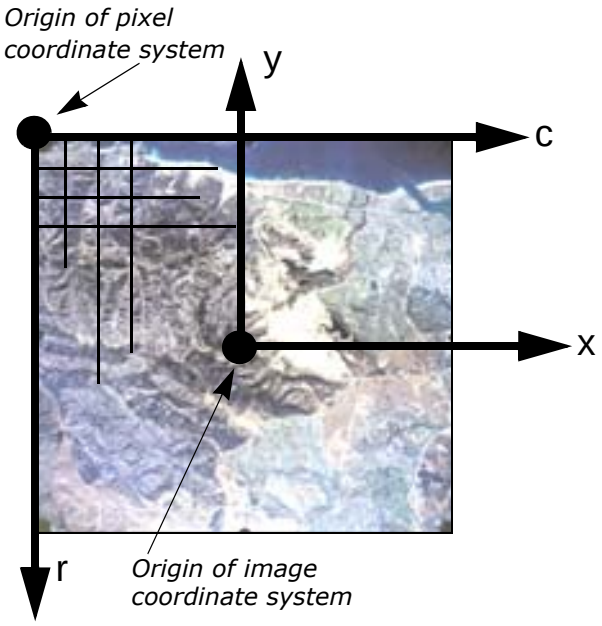


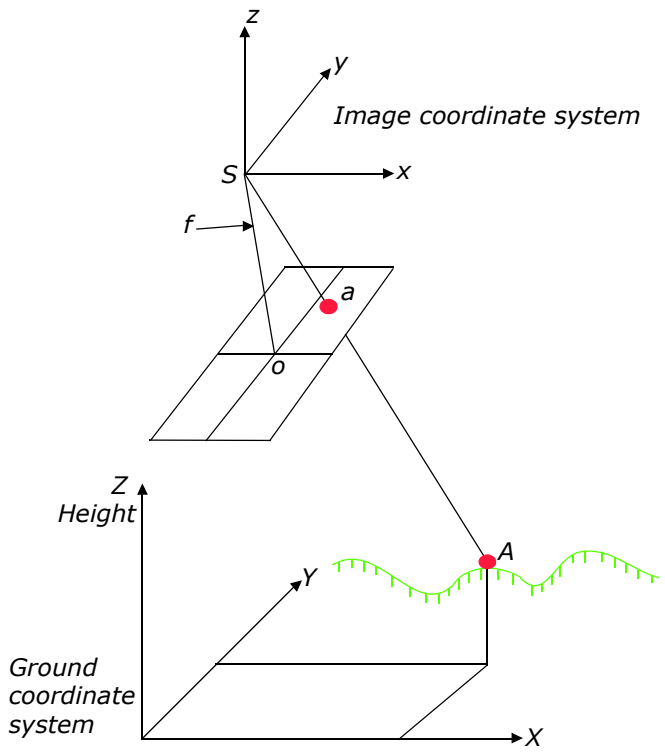
Image Coordinate System

An image coordinate system or an image plane coordinate system is usually defined as a 2D coordinate system occurring on the image plane with its origin at the image center. The origin of the image coordinate system is also referred to as the principal point. On aerial photographs, the principal point is defined as the intersection of opposite fiducial marks as illustrated by axes x and y as in Figure 14. Image coordinates are used to describe positions on the film plane. Image coordinate units are usually millimeters or microns.

Image Space Coordinate System

An image space coordinate system (Figure 15) is identical to image coordinates, except that it adds a third axis (z). The origin of the image space coordinate system is defined at the perspective center *S* as shown in Figure 15. The perspective center is commonly the lens of the camera as it existed when the photograph was captured. Its x-axis and y-axis are parallel to the x-axis and y-axis in the image plane coordinate system. The z-axis is the optical axis; therefore, the z value of an image point in the image space coordinate system is usually equal to the focal length of the camera (f). Image space coordinates are used to describe positions inside the camera, and usually use units in millimeters or microns. This coordinate system is referenced as image space coordinates (x, y, z) in this chapter.

Figure 15: Image Space and Ground Space Coordinate System



Ground Coordinate System

A ground coordinate system is usually defined as a 3D coordinate system that utilizes a known geographic map projection. Ground coordinates (X, Y, Z) are usually expressed in feet or meters. The Z value is elevation above mean sea level for a given vertical datum. This coordinate system is referenced as ground coordinates (X, Y, Z) in this chapter.

Geocentric and Topocentric Coordinate System

Most photogrammetric applications account for the curvature of the Earth in their calculations. This is done by adding a correction value or by computing geometry in a coordinate system that includes curvature. Two such systems are geocentric and topocentric coordinates.

A geocentric coordinate system has its origin at the center of the Earth ellipsoid. The Z-axis equals the rotational axis of the Earth, and the X-axis passes through the Greenwich meridian. The Y-axis is perpendicular to both the Z-axis and X-axis, so as to create a three-dimensional coordinate system that follows the right hand rule.

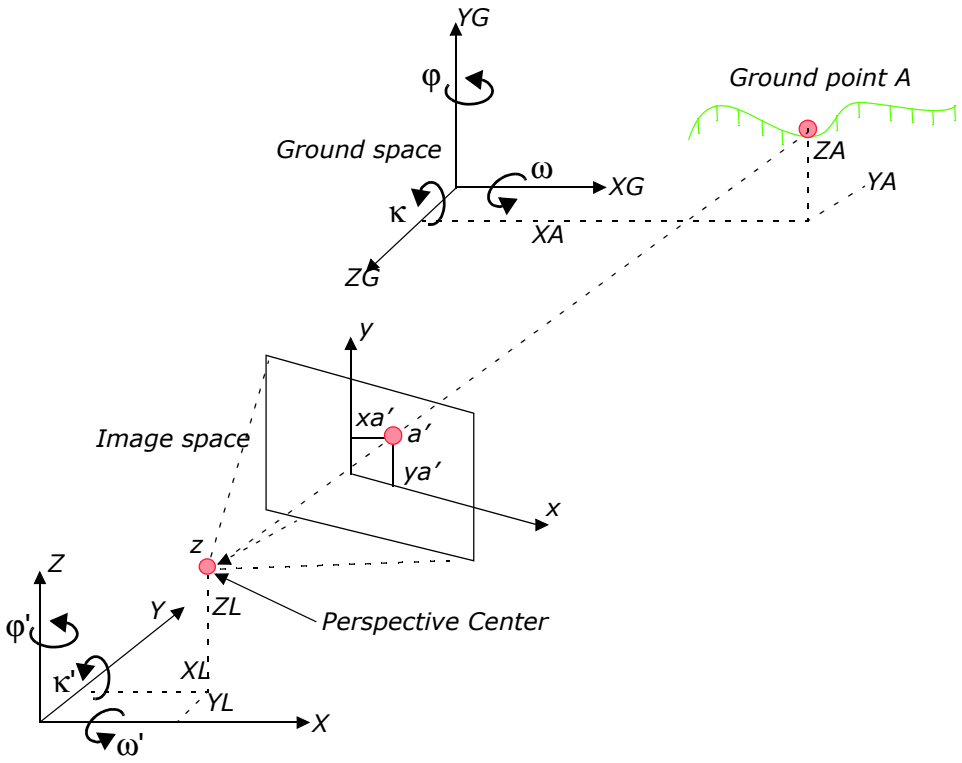
A topocentric coordinate system has its origin at the center of the image projected on the Earth ellipsoid. The three perpendicular coordinate axes are defined on a tangential plane at this center point. The plane is called the reference plane or the local datum. The x-axis is oriented eastward, the y-axis northward, and the z-axis is vertical to the reference plane (up).

For simplicity of presentation, the remainder of this chapter does not explicitly reference geocentric or topocentric coordinates. Basic photogrammetric principles can be presented without adding this additional level of complexity.

Terrestrial Photography

Photogrammetric applications associated with terrestrial or ground-based images utilize slightly different image and ground space coordinate systems. Figure 16 illustrates the two coordinate systems associated with image space and ground space.

Figure 16: Terrestrial Photography



The image and ground space coordinate systems are right-handed coordinate systems. Most terrestrial applications use a ground space coordinate system that was defined using a localized Cartesian coordinate system.

The image space coordinate system directs the z-axis toward the imaged object and the y-axis directed North up. The image x-axis is similar to that used in aerial applications. The $X_{L,}$ $Y_{L,}$ and Z_L coordinates define the position of the perspective center as it existed at the time of image capture. The ground coordinates of ground point *A* ($X_{A,}$ $Y_{A,}$ and Z_A) are defined within the ground space coordinate system ($X_{G,}$ $Y_{G,}$ and Z_G).

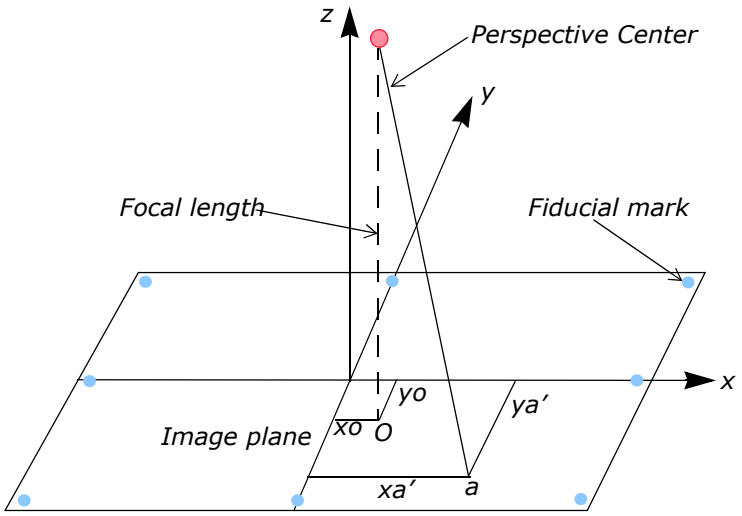
With this definition, three rotation angles ω (Omega), φ (Phi), and κ (Kappa) define the orientation of the image. You can also use the ground (X, Y, Z) coordinate system to directly define GCPs. Thus, GCPs do not need to be transformed. Then the definition of rotation angles ω′, φ′, and κ′ are different, as shown in Figure 16.

Interior Orientation

Interior orientation defines the internal geometry of a camera or sensor as it existed at the time of image capture. The variables associated with image space are obtained during the process of defining interior orientation. Interior orientation is primarily used to transform the image pixel coordinate system or other image coordinate measurement systems to the image space coordinate system.

Figure 17 illustrates the variables associated with the internal geometry of an image captured from an aerial camera, where *o* represents the principal point and *a* represents an image point.

Figure 17: Internal Geometry



The internal geometry of a camera is defined by specifying the following variables:

- principal point
- focal length
- fiducial marks
- lens distortion

Principal Point and Focal Length

The principal point is mathematically defined as the intersection of the perpendicular line through the perspective center of the image plane. The length from the principal point to the perspective center is called the focal length (Wang 1990).

The image plane is commonly referred to as the focal plane. For wide-angle aerial cameras, the focal length is approximately 152 mm, or 6 inches. For some digital cameras, the focal length is 28 mm. Prior to conducting photogrammetric projects, the focal length of a metric camera is accurately determined or calibrated in a laboratory environment.

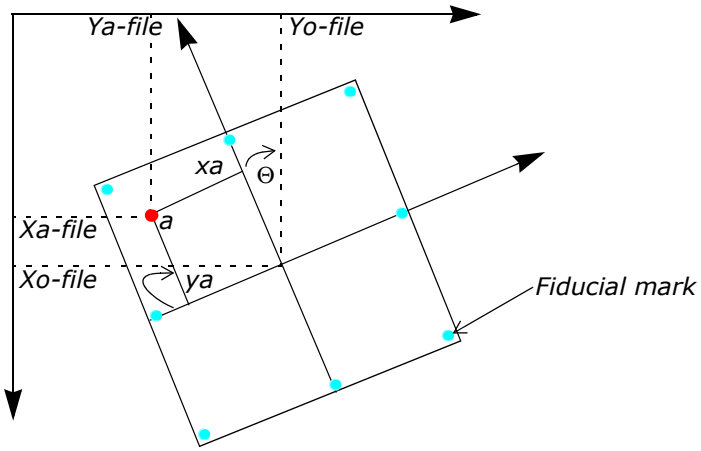
The optical definition of principal point is the image position where the optical axis intersects the image plane. In the laboratory, this is calibrated in two forms: principal point of autocollimation and principal point of symmetry, which can be seen from the camera calibration report. Most applications prefer to use the principal point of symmetry since it can best compensate for any lens distortion.

Fiducial Marks

As stated previously, one of the steps associated with calculating interior orientation involves determining the image position of the principal point for each image in the project. Therefore, the image positions of the fiducial marks are measured on the image, and then compared to the calibrated coordinates of each fiducial mark.

Since the image space coordinate system has not yet been defined for each image, the measured image coordinates of the fiducial marks are referenced to a pixel or file coordinate system. The pixel coordinate system has an *x* coordinate (column) and a *y* coordinate (row). The origin of the pixel coordinate system is the upper left corner of the image having a row and column value of 0 and 0, respectively. Figure 18 illustrates the difference between the pixel coordinate system and the image space coordinate system.

Figure 18: Pixel Coordinate System vs. Image Space Coordinate System



Using a 2D affine transformation, the relationship between the pixel coordinate system and the image space coordinate system is defined. The following 2D affine transformation equations can be used to determine the coefficients required to transform pixel coordinate measurements to the corresponding image coordinate values:

$$x = a_1 + a_2X + a_3Y$$
$$y = b_1 + b_2X + b_3Y$$

The *x* and *y* image coordinates associated with the calibrated fiducial marks and the *X* and *Y* pixel coordinates of the measured fiducial marks are used to determine six affine transformation coefficients. The resulting six coefficients can then be used to transform each set of row (*y*) and column (*x*) pixel coordinates to image coordinates.

The quality of the 2D affine transformation is represented using a root mean square (RMS) error. The RMS error represents the degree of correspondence between the calibrated fiducial mark coordinates and their respective measured image coordinate values. Large RMS errors indicate poor correspondence. This can be attributed to film deformation, poor scanning quality, out-of-date calibration information, or image mismeasurement.

The affine transformation also defines the translation between the origin of the pixel coordinate system and the image coordinate system ($x_{o\text{-}file}$ and $y_{o\text{-}file}$). Additionally, the affine transformation takes into consideration rotation of the image coordinate system by considering angle Θ. A scanned image of an aerial photograph is normally rotated due to the scanning procedure.

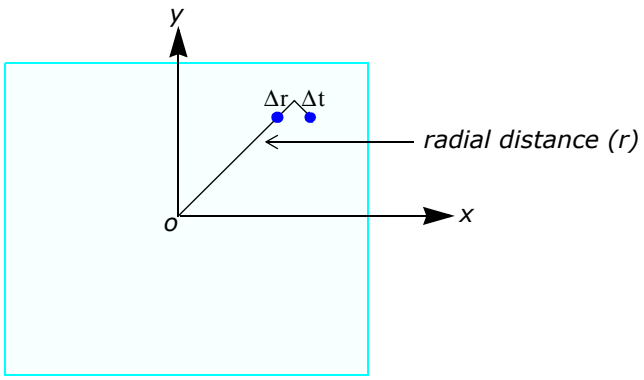
The degree of variation between the x-axis and y-axis is referred to as nonorthogonality. The 2D affine transformation also considers the extent of nonorthogonality. The scale difference between the x-axis and the y-axis is also considered using the affine transformation.

NOTE: Stereo Analyst allows for the input of affine transform coefficients for the creation of a DSM in the Create Stereo Model tool.

Lens Distortion

Lens distortion deteriorates the positional accuracy of image points located on the image plane. Two types of radial lens distortion exist: radial and tangential lens distortion. Lens distortion occurs when light rays passing through the lens are bent, thereby changing directions and intersecting the image plane at positions deviant from the norm. Figure 19 illustrates the difference between radial and tangential lens distortion.

Figure 19: Radial vs. Tangential Lens Distortion



Radial lens distortion causes imaged points to be distorted along radial lines from the principal point *o*. The effect of radial lens distortion is represented as Δr. Radial lens distortion is also commonly referred to as symmetric lens distortion. Tangential lens distortion occurs at right angles to the radial lines from the principal point. The effect of tangential lens distortion is represented as Δt. Because tangential lens distortion is much smaller in magnitude than radial lens distortion, it is considered negligible. The effects of lens distortion are commonly determined in a laboratory during the camera calibration procedure.

The effects of radial lens distortion throughout an image can be approximated using a polynomial. The following polynomial is used to determine coefficients associated with radial lens distortion:

$$\Delta r = k_0 r + k_1 r^3 + k_2 r^5$$

In the equation above, Δr represents the radial distortion along a radial distance *r* from the principal point (Wolf 1983). In most camera calibration reports, the lens distortion value is provided as a function of radial distance from the principal point or field angle.

LPS Project Manager accommodates radial lens distortion parameters in both radial and tangential lens distortion.

Three coefficients, k_0, k_1, and k_2, are computed using statistical techniques. Once the coefficients are computed, each measurement taken on an image is corrected for radial lens distortion.

Exterior Orientation

Exterior orientation defines the position and angular orientation of the camera that captured an image. The variables defining the position and orientation of an image are referred to as the elements of exterior orientation. The elements of exterior orientation define the characteristics associated with an image at the time of exposure or capture. The positional elements of exterior orientation include X_o, Y_o, and Z_o. They define the position of the perspective center (*O*) with respect to the ground space coordinate system (*X, Y,* and *Z*). Z_o is commonly referred to as the height of the camera above sea level, which is commonly defined by a datum.

The angular or rotational elements of exterior orientation describe the relationship between the ground space coordinate system (*X, Y,* and *Z*) and the image space coordinate system (*x, y,* and *z*). Three rotation angles are commonly used to define angular orientation. They are Omega (ω), Phi (φ), and Kappa (κ). Figure 20 illustrates the elements of exterior orientation. Figure 21 illustrates the individual angles (ω, φ, and κ) of exterior orientation.

Figure 20: Elements of Exterior Orientation

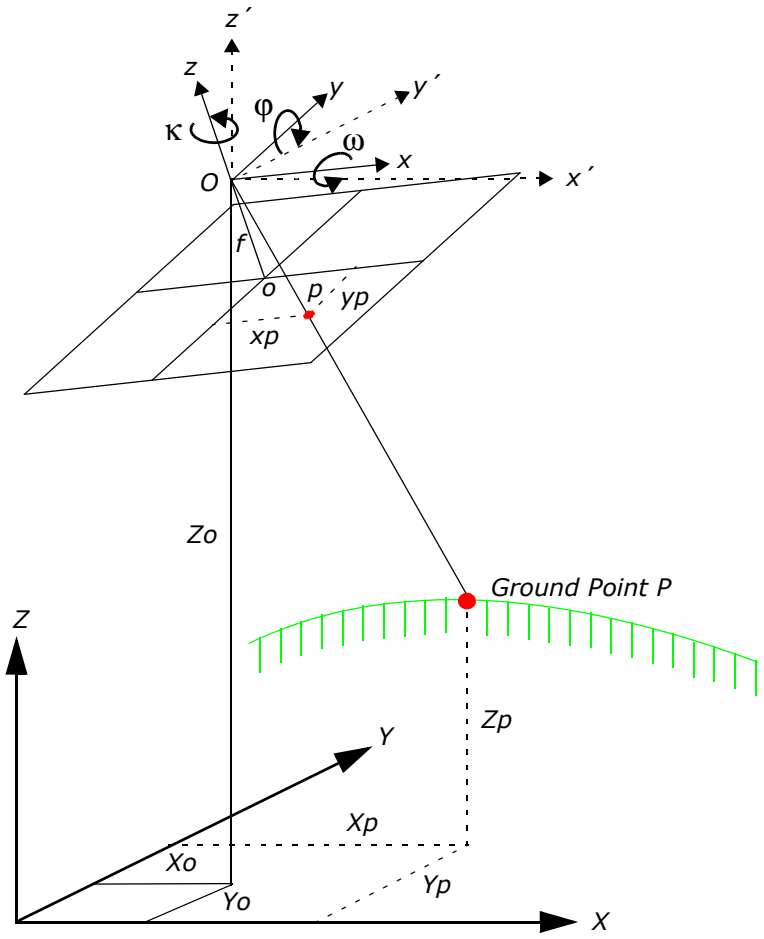
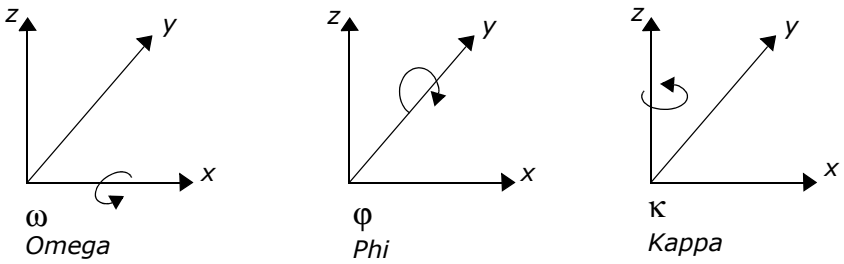


Figure 21: Omega, Phi, and Kappa



Omega is a rotation about the photographic x-axis, Phi is a rotation about the photographic y-axis, and Kappa is a rotation about the photographic z-axis, which are defined as being positive if they are counterclockwise when viewed from the positive end of their respective axis. Different conventions are used to define the order and direction of the three rotation angles (Wang 1990). The International Society of Photogrammetry and Remote Sensing (ISPRS) recommends the use of the ω, φ, κ convention. The photographic z-axis is equivalent to the optical axis (focal length). The *x′, y′,* and *z′* coordinates are parallel to the ground space coordinate system.

Using the three rotation angles, the relationship between the image space coordinate system (*x, y,* and *z*) and ground space coordinate system (*X, Y,* and *Z* or *x′, y′,* and *z′*) can be determined. A 3×3 matrix defining the relationship between the two systems is used. This is referred to as the orientation or rotation matrix, *M.* The rotation matrix can be defined as follows:

$$M = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix}$$

The rotation matrix is derived by applying a sequential rotation of Omega about the x-axis, Phi about the y-axis, and Kappa about the z-axis.

The Collinearity Equation

The following section defines the relationship between the camera/sensor, the image, and the ground. Most photogrammetric tools utilize the following formulas in one form or another.

NOTE: Stereo Analyst uses a form of the collinearity equation to continuously determine the 3D position of the floating cursor.

With reference to Figure 20, an image vector *a* can be defined as the vector from the exposure station *O* to the image point *p*. A ground space or object space vector *A* can be defined as the vector from the exposure station *O* to the ground point *P*. The image vector and ground vector are collinear, inferring that a line extending from the exposure station to the image point and to the ground is linear.

The image vector and ground vector are only collinear if one is a scalar multiple of the other. Therefore, the following statement can be made:

$$a = kA$$

where *k* is a scalar multiple. The image and ground vectors must be within the same coordinate system. Therefore, image vector *a* is comprised of the following components:

$$a = \begin{bmatrix} x_p - x_o \\ y_p - y_o \\ -f \end{bmatrix}$$

where *xo* and *yo* represent the image coordinates of the principal point.

Similarly, the ground vector can be formulated as follows:

$$A = \begin{bmatrix} X_p - X_o \\ Y_p - Y_o \\ Z_p - Z_o \end{bmatrix}$$

In order for the image and ground vectors to be within the same coordinate system, the ground vector must be multiplied by the rotation matrix *M*. The following equation can be formulated:

$$a = kMA$$

where

$$\begin{bmatrix} x_p - x_o \\ y_p - y_o \\ -f \end{bmatrix} = kM \begin{bmatrix} X_p - X_o \\ Y_p - Y_o \\ Z_p - Z_o \end{bmatrix}$$

The previous equation defines the relationship between the perspective center of the camera/sensor exposure station and ground point *P* appearing on an image with an image point location of *p*. This equation forms the basis of the collinearity condition that is used in most photogrammetric operations. The collinearity condition specifies that the exposure station of the image, ground point, and its corresponding image point location must all lay along a straight line, thereby being collinear. Two equations comprise the collinearity condition:

$$x_p - x_o = -f\left[\frac{m_{11}(X_p - X_{o_1}) + m_{12}(Y_p - Y_{o_1}) + m_{13}(Z_p - Z_{o_1})}{m_{31}(X_p - X_{o_1}) + m_{32}(Y_p - Y_{o_1}) + m_{33}(Z_p - Z_{o_1})}\right]$$

$$y_p - y_o = -f\left[\frac{m_{21}(X_p - X_{o_1}) + m_{22}(Y_p - Y_{o_1}) + m_{23}(Z_p - Z_{o_1})}{m_{31}(X_p - X_{o_1}) + m_{32}(Y_p - Y_{o_1}) + m_{33}(Z_p - Z_{o_1})}\right]$$

One set of equations can be formulated for each ground point appearing on an image. The collinearity condition is commonly used to define the relationship between the camera/sensor, the image, and the ground.

Digital Mapping Solutions

Digital photogrammetry is used for many applications, ranging from orthorectification, automated elevation extraction, stereopair creation, stereo feature collection, highly accurate 3D point determination, and GCP extension.

For any of the aforementioned tasks to be undertaken, a relationship between the camera/sensor, the image(s) in a project, and the ground must be defined. The following variables are used to define the relationship:

- exterior orientation parameters,
- interior orientation parameters, and
- camera or sensor model information.

Well-known obstacles in photogrammetry include defining the interior and exterior orientation parameters for each image in a project using a minimum number of GCPs. Due to the costs and labor intensive procedures associated with collecting ground control, most photogrammetric applications do not have an abundant number of GCPs. Additionally, the exterior orientation parameters associated with an image are normally unknown.

Depending on the input data provided, photogrammetric techniques such as space resection, space forward intersection, and bundle block adjustment are used to define the variables required to perform orthorectification, automated DEM extraction, stereopair creation, highly accurate point determination, and control point extension.

Space Resection

Space resection is a technique that is commonly used to determine the exterior orientation parameters associated with one image or many images based on known GCPs. Space resection uses the collinearity condition. Space resection using the collinearity condition specifies that, for any image, the exposure station, the ground point, and its corresponding image point must lay along a straight line.

If a minimum number of three GCPs are known in the X, Y, and Z direction, space resection techniques can be used to determine the six exterior orientation parameters associated with an image. Space resection assumes that camera information is available.

Space resection is commonly used to perform single frame orthorectification where one image is processed at a time. If multiple images are being used, space resection techniques require that a minimum of three GCPs be located on each image being processed.

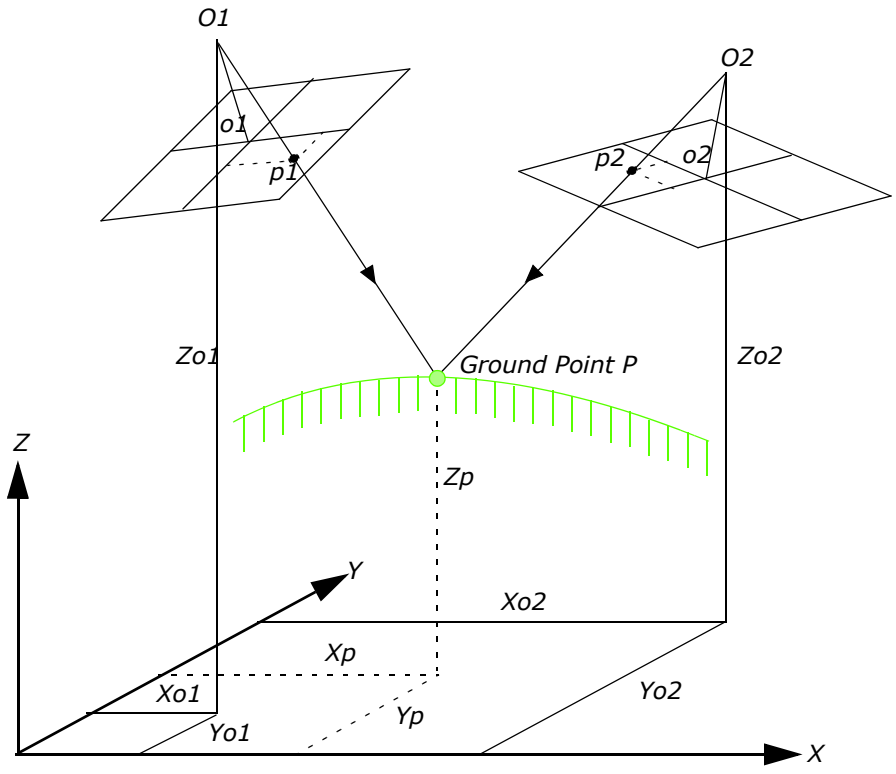
Using the collinearity condition, the positions of the exterior orientation parameters are computed. Light rays originating from at least three GCPs intersect through the image plane through the image positions of the GCPs and resect at the perspective center of the camera or sensor. Using least squares adjustment techniques, the most probable positions of exterior orientation can be computed. Space resection techniques can be applied to one image or multiple images.

Space Forward Intersection

Space forward intersection is a technique that is commonly used to determine the ground coordinates X, Y, and Z of points that appear in the overlapping areas of two or more images based on known interior orientation and known exterior orientation parameters. The collinearity condition is enforced, stating that the corresponding light rays from the two exposure stations pass through the corresponding image points on the two images and intersect at the same ground point. Figure 22 illustrates the concept associated with space forward intersection.

NOTE: This concept is key for the determination of 3D ground coordinate information in Stereo Analyst.

Figure 22: Space Forward Intersection



Space forward intersection techniques assume that the exterior orientation parameters associated with the images are known. Using the collinearity equations, the exterior orientation parameters along with the image coordinate measurements of point *p1* on Image 1 and point *p2* on Image 2 are input to compute the X_p, Y_p, and Z_p coordinates of ground point *P*.

Space forward intersection techniques can also be used for applications associated with collecting GCPs, cadastral mapping using airborne surveying techniques, and highly accurate point determination.

Bundle Block Adjustment

For mapping projects having more than two images, the use of space intersection and space resection techniques is limited. This can be attributed to the lack of information required to perform these tasks. For example, it is fairly uncommon for the exterior orientation parameters to be highly accurate for each photograph or image in a project, since these values are generated photogrammetrically. Airborne GPS and INS techniques normally provide initial approximations to exterior orientation, but the final values for these parameters must be adjusted to attain higher accuracies.

Similarly, rarely are there enough accurate GCPs for a project of thirty or more images to perform space resection (that is, a minimum of 90 is required). In the case that there are enough GCPs, the time required to identify and measure all of the points would be costly.

The costs associated with block triangulation and orthorectification are largely dependent on the number of GCPs used. To minimize the costs of a mapping project, fewer GCPs are collected and used. To ensure that high accuracies are attained, an approach known as bundle block adjustment is used.

A bundle block adjustment is best defined by examining the individual words in the term. A bundled solution is computed including the exterior orientation parameters of each image in a block and the X, Y, and Z coordinates of tie points and adjusted GCPs. A block of images contained in a project is simultaneously processed in one solution. A statistical technique known as least squares adjustment is used to estimate the bundled solution for the entire block while also minimizing and distributing error.

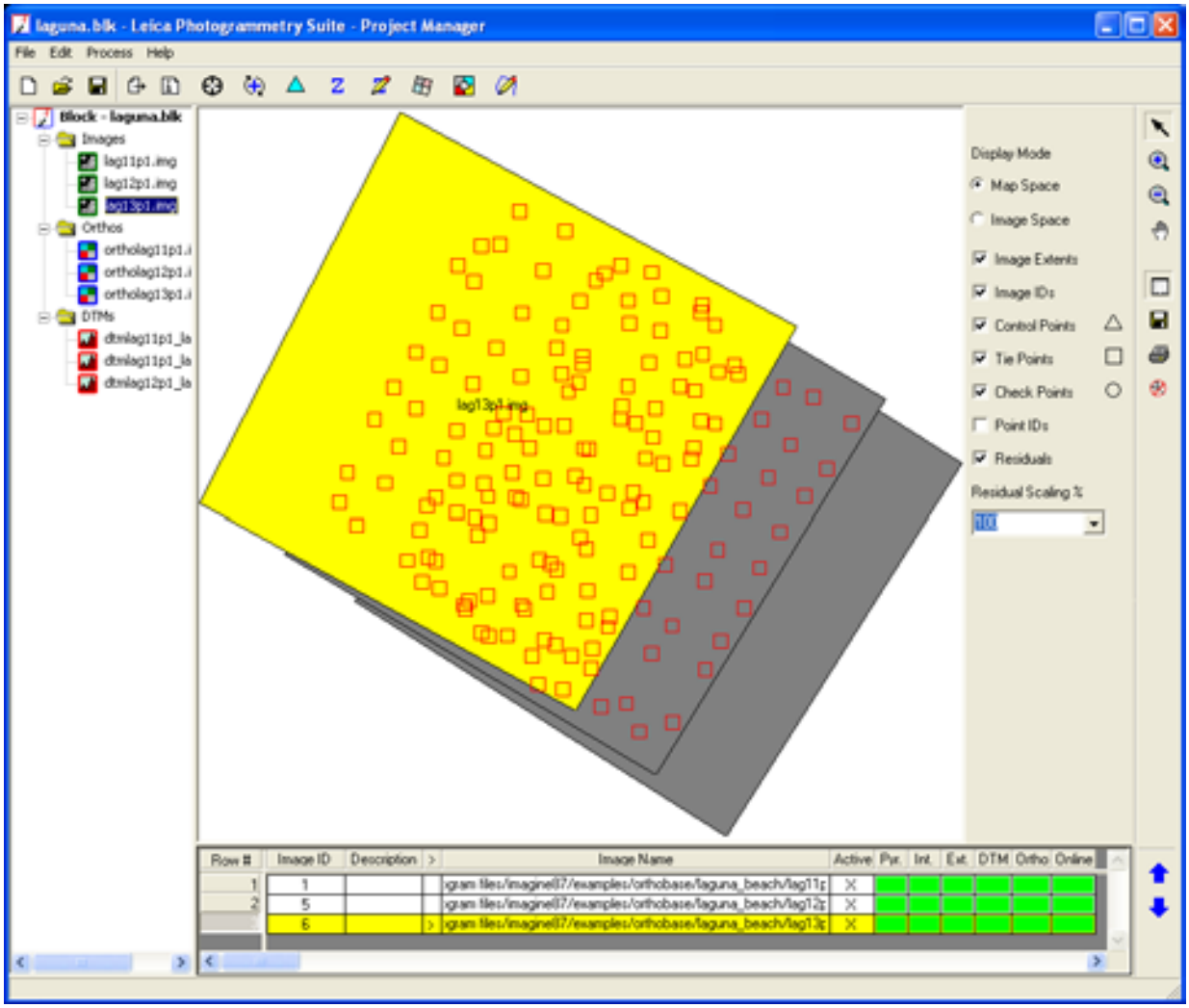
Block triangulation is the process of defining the mathematical relationship between the images contained within a block, the camera or sensor model, and the ground. Once the relationship has been defined, accurate imagery and geographic information concerning the surface of the Earth can be created and collected in 3D.

When processing frame camera, digital camera, videography, and nonmetric camera imagery, block triangulation is commonly referred to as aerial triangulation (AT). When processing imagery collected with a pushbroom sensor, block triangulation is commonly referred to as triangulation.

There are several models for block triangulation. The common models used in photogrammetry are block triangulation with the strip method, the independent model method, and the bundle method. Among them, the bundle block adjustment is the most rigorous of the above methods, considering the minimization and distribution of errors. Bundle block adjustment uses the collinearity condition as the basis for formulating the relationship between image space and ground space.

In order to understand the concepts associated with bundle block adjustment, an example comprising ten images with multiple GCPs whose X, Y, and Z coordinates are known is used. Additionally, six tie points are available. Figure 23 illustrates the photogrammetric configuration.

Figure 23: Photogrammetric Block Configuration



Forming the Collinearity Equations

For each measured GCP, there are two corresponding image coordinates (x and y). Thus, two collinearity equations can be formulated to represent the relationship between the ground point and the corresponding image measurements. In the context of bundle block adjustment, these equations are known as observation equations.

If a GCP has been measured on the overlapping area of two images, four equations can be written: two for image measurements on the left image comprising the pair and two for the image measurements made on the right image comprising the pair. Thus, GCP *A* measured on the overlap area of image left and image right has four collinearity formulas:

$$x_{a_1} - x_o = -f\left[\frac{m_{11}(X_A - X_{o_1}) + m_{12}(Y_A - Y_{o_1}) + m_{13}(Z_A - Z_{o_1})}{m_{31}(X_A - X_{o_1}) + m_{32}(Y_A - Y_{o_1}) + m_{33}(Z_A - Z_{o_1})}\right]$$

$$y_{a_1} - y_o = -f\left[\frac{m_{21}(X_A - X_{o_1}) + m_{22}(Y_A - Y_{o_1}) + m_{23}(Z_A - Z_{o_1})}{m_{31}(X_A - X_{o_1}) + m_{32}(Y_A - Y_{o_1}) + m_{33}(Z_A - Z_{o_1})}\right]$$

$$x_{a_2} - x_o = -f\left[\frac{m'_{11}(X_A - X_{o_2}) + m'_{12}(Y_A - Y_{o_2}) + m'_{13}(Z_A - Z_{o_2})}{m'_{31}(X_A - X_{o_2}) + m'_{32}(Y_A - Y_{o_2}) + m'_{33}(Z_A - Z_{o_2})}\right]$$

$$y_{a_2} - y_o = -f\left[\frac{m'_{21}(X_A - X_{o_2}) + m'_{22}(Y_A - Y_{o_2}) + m'_{23}(Z_A - Z_{o_2})}{m'_{31}(X_A - X_{o_2}) + m'_{32}(Y_A - Y_{o_2}) + m'_{33}(Z_A - Z_{o_2})}\right]$$

One image measurement of GCP *A* on Image 1:

$$x_{a_1}, y_{a_1}$$

One image measurement of GCP *A* on Image 2:

$$x_{a_2}, y_{a_2}$$

Positional elements of exterior orientation on Image 1:

$$X_{o_1}, Y_{o_1}, Z_{o_1}$$

Positional elements of exterior orientation on Image 2:

$$X_{o_2}, Y_{o_2}, Z_{o_2}$$

If three GCPs have been measured on the overlap area of two images, twelve equations can be formulated, which include four equations for each GCP.

Additionally, if six tie points have been measured on the overlap areas of the two images, twenty-four equations can be formulated, which include four for each tie point. This is a total of 36 observation equations.

The previous scenario has the following unknowns:

- six exterior orientation parameters for the left image (that is, X, Y, Z, Omega, Phi, Kappa),
- six exterior orientation parameters for the right image (that is, X, Y, Z, Omega, Phi, Kappa), and
- X, Y, and Z coordinates of the tie points. Thus, for six tie points, this includes eighteen unknowns (six tie points times three X, Y, Z coordinates).

The total number of unknowns is 30. The overall quality of a bundle block adjustment is largely a function of the quality and redundancy in the input data. In this scenario, the redundancy in the project can be computed by subtracting the number of unknowns, 30, by the number of knowns, 36. The resulting redundancy is six. This term is commonly referred to as the degrees of freedom in a solution.

Once each observation equation is formulated, the collinearity condition can be solved using an approach referred to as least squares adjustment.

Least Squares Adjustment

Least squares adjustment is a statistical technique that is used to estimate the unknown parameters associated with a solution while also minimizing error within the solution. Least squares adjustment techniques are used to:

- Estimate or adjust the values associated with exterior orientation.
- Estimate the X, Y, and Z coordinates associated with tie points.
- Estimate or adjust the values associated with interior orientation.
- Minimize and distribute data error through the network of observations.

Data error is attributed to the inaccuracy associated with the input GCP coordinates, measured tie point and GCP image positions, camera information, and systematic errors.

The least squares approach requires iterative processing until a solution is attained. A solution is obtained when the residuals, or errors, associated with the input data are minimized.

The least squares approach involves determining the corrections to the unknown parameters based on the criteria of minimizing input measurement residuals. The residuals are derived from the difference between the measured and computed value for any particular measurement in a project. In the block triangulation process, a functional model can be formed based upon the collinearity equations.

The functional model refers to the specification of an equation that can be used to relate measurements to parameters. In the context of photogrammetry, measurements include the image locations of GCPs and GCP coordinates, while the exterior orientations of all the images are important parameters estimated by the block triangulation process.

The residuals, which are minimized, include the image coordinates of the GCPs and tie points along with the known ground coordinates of the GCPs. A simplified version of the least squares condition can be broken down into a formula as follows:

$$V = AX - L \text{ } \textit{including a weight matrix P}$$

where

- *V* = the matrix containing the image coordinate residuals
- *A* = the matrix containing the partial derivatives with respect to the unknown parameters including exterior orientation; interior orientation; X,Y, Z tie point; and GCP coordinates
- *X* = the matrix containing the corrections to the unknown parameters
- *L* = the matrix containing the input observations (that is, image coordinates and GCP coordinates)

The components of the least squares condition are directly related to the functional model based on collinearity equations. The *A* matrix is formed by differentiating the functional model, which is based on collinearity equations, with respect to the unknown parameters such as exterior orientation. The *L* matrix is formed by subtracting the initial results obtained from the functional model with newly estimated results determined from a new iteration of processing. The *X* matrix contains the corrections to the unknown exterior orientation parameters. The *X* matrix is calculated in the following manner:

$$X = (A^tPA)^{-1}A^tPL$$

where

- X = the matrix containing the corrections to the unknown parameters

A = the matrix containing the partial derivatives with respect to the unknown parameters

^{t} = the matrix transposed

P = the matrix containing the weights of the observations

L = the matrix containing the observations

Once a least squares iteration of processing is completed, the corrections to the unknown parameters are added to the initial estimates. For example, if initial approximations to exterior orientation are provided from airborne GPS and INS information, the estimated corrections computed from the least squares adjustment are added to the initial value to compute the updated exterior orientation values. This iterative process of least squares adjustment continues until the corrections to the unknown parameters are less than a threshold (commonly referred to as a convergence value).

The *V* residual matrix is computed at the end of each iteration of processing. Once an iteration is completed, the new estimates for the unknown parameters are used to recompute the input observations such as the image coordinate values. The difference between the initial measurements and the new estimates is obtained to provide the residuals. Residuals provide preliminary indications of the accuracy of a solution. The residual values indicate the degree to which a particular observation (input) fits with the functional model. For example, the image residuals have the capability of reflecting GCP collection in the field. After each successive iteration of processing, the residuals become smaller until they are satisfactorily minimized.

Once the least squares adjustment is completed, the block triangulation results include:

- final exterior orientation parameters of each image in a block and their accuracy,
- final interior orientation parameters of each image in a block and their accuracy,
- X, Y, and Z tie point coordinates and their accuracy,
- adjusted GCP coordinates and their residuals, and
- image coordinate residuals.

The results from the block triangulation are then used as the primary input for the following tasks:

- stereopair creation
- feature collection
- highly accurate point determination
- DEM extraction

- orthorectification

NOTE: Stereo Analyst uses the results from the block triangulation for the automatic display and creation of DSMs.

Automatic Gross Error Detection

Normal random errors are subject to statistical normal distribution. In contrast, gross errors refer to errors that are large and are not subject to normal distribution. The gross errors among the input data for triangulation can lead to unreliable results. Research during the 80s in the photogrammetric community resulted in significant achievements in automatic gross error detection in the triangulation process (for example, Kubik 1982, Li 1983, Li 1985, Jacobsen 1980, El-Hakin 1984, and Wang 1988).

Methods for gross error detection began with residual checking using data-snooping and were later extended to robust estimation (Wang 1990). The most common robust estimation method is the iteration with selective weight functions.

Based on the scientific research results from the photogrammetric community, LPS Project Manager offers two robust error detection methods within the triangulation process.

It is worth mentioning that the effect of the automatic error detection depends not only on the mathematical model, but also depends on the redundancy in the block. Therefore, more tie points in more overlap areas contribute better gross error detection. In addition, inaccurate GCPs can distribute their errors to correct tie points; therefore, the ground and image coordinates of GCPs should have better accuracy than tie points when comparing them within the same scale space.

Next

Next, you can learn about stereo viewing and feature collection. This information prepares you to start viewing and digitizing in stereo.

Stereo Viewing and 3D Feature Collection

Introduction

This chapter describes the concepts associated with stereo viewing, parallax, the 3D floating cursor, and the theory associated with collecting 3D information from DSMs.

Principles of Stereo Viewing

Stereoscopic Viewing

On a daily basis, we unconsciously perceive and measure depth using our eyes. Persons using both eyes to view an object have binocular vision. Persons using one eye to view an object have monocular vision. The perception of depth through binocular vision is referred to as stereoscopic viewing.

With stereoscopic viewing, depth information can be perceived with great detail and accuracy. Stereo viewing allows the human brain to judge and perceive changes in depth and volume. In photogrammetry, stereoscopic depth perception plays a vital role in creating and viewing 3D representations of the surface of the Earth. As a result, geographic information can be collected to a greater accuracy as compared to traditional monoscopic techniques.

Stereo feature collection techniques provide greater GIS data collection and update accuracy for the following reasons:

- Sensor model information derived from block triangulation eliminates errors associated with the uncertainty of sensor model position and orientation. Accurate image position and orientation information is required for the highly accurate determination of 3D information.
- Systematic errors associated with raw photography and imagery are considered and minimized during the block triangulation process.
- The collection of 3D coordinate information using stereo viewing techniques is not dependent and reliant on a DEM as an input source. Changes and variations in depth perception can be perceived and automatically transformed using sensor model information and raw imagery. Therefore, DTMs containing error are not introduced into the collected GIS data.

Digital photogrammetric techniques used in Stereo Analyst extend the perception and interpretation of depth to include the measurement and collection of 3D information.

How it Works

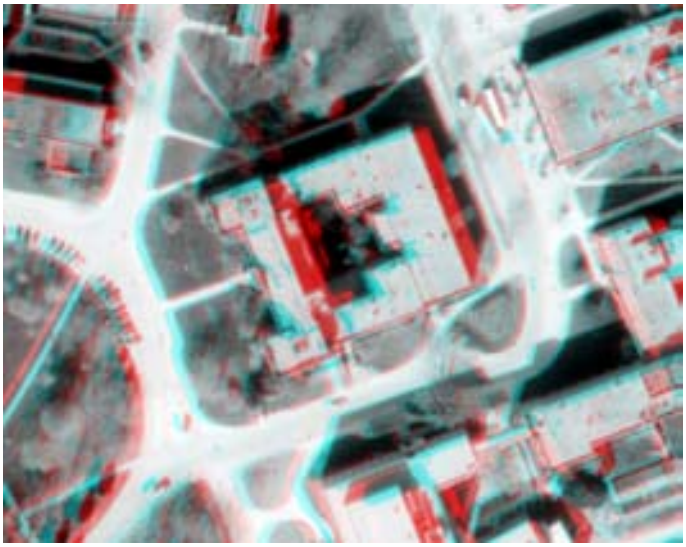
A true stereo effect is achieved when two overlapping images (a stereopair), or photographs of a common area captured from two different vantage points are rendered and viewed simultaneously. The stereo effect, or ability to view with measurable depth perception, is provided by a parallax effect generated from the two different acquisition points.

This is analogous to the depth perception you achieve by looking at a feature with your two eyes. The distance between your eyes represents the two vantage points similar to two independent photos, as in Figure 24.

Figure 24: Two Overlapping Photos

The importance is that by viewing the surface of the Earth in stereo, you can interpret, measure, and delineate map features in 3D. The net benefit is that many map features are more interpretable, with a higher degree of accuracy in stereo than in 2D with a single image. Figure 25 shows a stereo view.

Figure 25: Stereo View



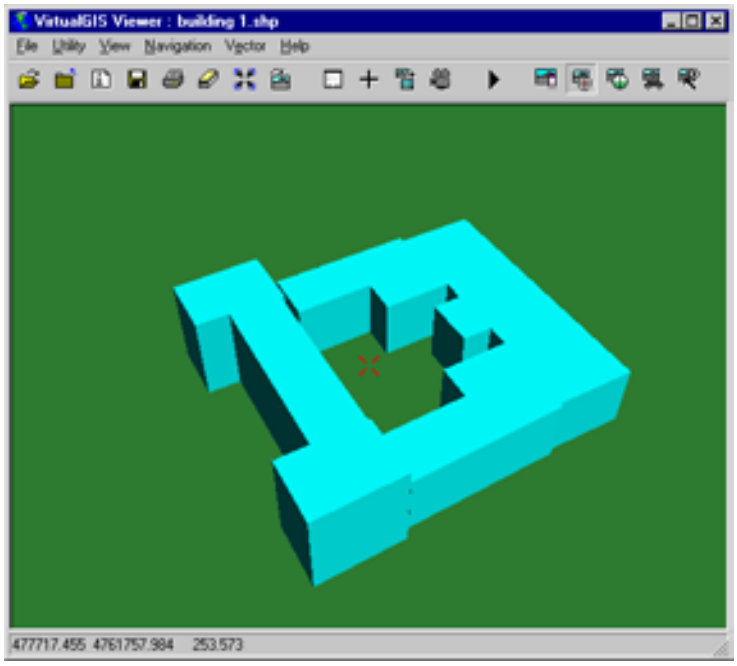
When viewing the features from two perspectives, (the left photo and the right photo), the brain automatically perceives the variation in depth between different objects and features as a difference in height. For example, while viewing a building in stereo, the brain automatically compares the relative positions of the building and the ground from the two different perspectives (that is, two overlapping images). The brain also determines which is closer and which is farther: the building or the ground. Thus, as left and right eyes view the overlap area of two images, depth between the top and bottom of a building is perceived automatically by the brain, and any changes in depth are due to changes in elevation.

During the stereo viewing process, the left eye concentrates on the object in the left image and the right eye concentrates on the object in the right image. As a result, a single 3D image is formed within the brain. The brain discerns height and variations in height by visually comparing the depths of various features. While the eyes move across the overlap area of the two photographs, a continuous 3D model of the Earth is formulated within the brain, since the eyes continuously perceive the change in depth as a function of change in elevation.

The 3D image formed by the brain is also referred to as a stereo model. Once the stereo model is formed, you notice relief, or vertical exaggeration, in the 3D model. A digital version of a stereo model, a DSM, can be created when sensor model information is associated with the left and right images comprising a stereopair. In Stereo Analyst, a DSM is formed using a stereopair and accurate sensor model information.

Using the stereo viewing and 3D feature collection capabilities of Stereo Analyst, changes and variations in elevation perceived by the brain can be translated to reflect real-world 3D information. Figure 26 shows an example of a 3D Shapefile created using Stereo Analyst, which displays in IMAGINE VirtualGIS.

Figure 26: 3D Shapefile Collected in Stereo Analyst



Stereo Models and Parallax

Stereo models provide a permanent record of 3D information pertaining to the given geographic area covered within the overlapping area of two images. Viewing a stereo model in stereo presents an abundant amount of 3D information to you. The availability of 3D information in a stereo model is made possible by the presence of what is referred to as stereoscopic parallax. There are two types of parallax: x-parallax and y-parallax.

X-parallax

Figure 27 illustrates the image positions of two ground points (A and B) appearing in the overlapping areas of two images. Ground point A is the top of a building, and ground point B is the ground.

Figure 27: Left and Right Images of a Stereopair

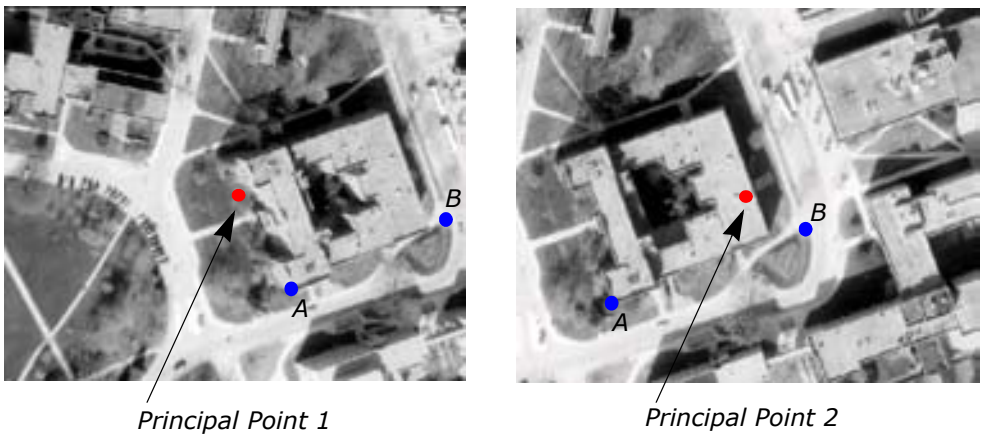
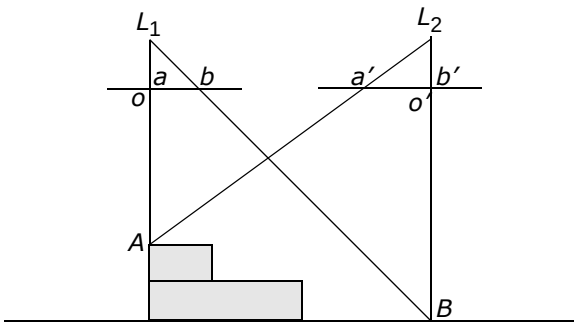


Figure 28 illustrates a profile view of the stereopair and the corresponding image positions of ground point A and ground point B.

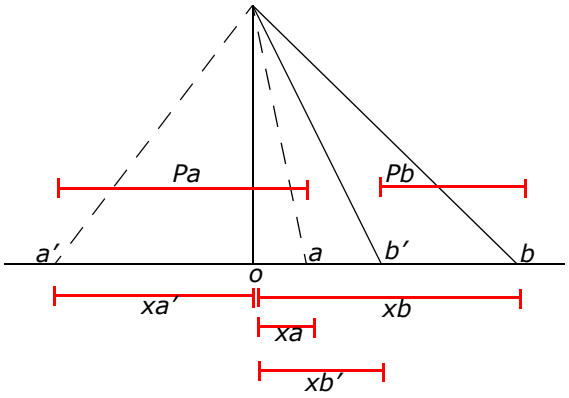
Figure 28: Profile View of a Stereopair



Ground points A and B appear on the left photograph (L_1) at image positions a and b, respectively. Due to the forward motion of the aircraft during photographic exposure, the same two ground points appear on the right photograph (L_2) at image positions a′ and b′. Since ground point A is at a higher elevation, the movement of image point *a* to position a′ on the right image is larger than the image movement of point *b*. This can be attributed to x-parallax.

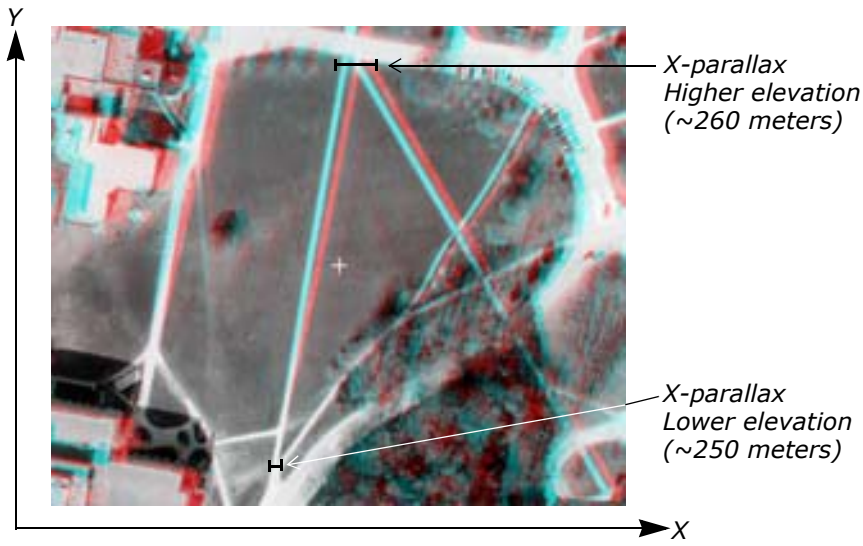
Figure 29 illustrates that the parallax associated with ground point A (Pa) is larger than the parallax associated with ground point B (Pb).

Figure 29: Parallax Comparison Between Points



Thus, the amount of x-parallax is influenced by the elevation of a ground point. Since the degree of topographic relief varies across a stereopair, the amount of x-parallax also varies. In essence, the brain perceives the variation in parallax between the ground and various features, and therefore judges the variations in elevation and height. Figure 30 illustrates the difference in elevation as a function of x-parallax.

Figure 30: Parallax Reflects Change in Elevation



Using 3D geographic imaging techniques, Stereo Analyst translates and transforms the x-parallax information associated with features recorded on a stereopair into quantitative height and elevation information.

Y-parallax

Under certain conditions and circumstances, viewing a DSM may be difficult. The following factors influence the quality of stereo viewing:

- Unequal flying height between adjacent photographic exposures. This effect causes a difference in scale between the left and right images. As a result, the 3D stereo view becomes distorted.
- Flight line misalignment during photographic collection. This results in large differences in photographic orientation between two overlapping images. As a result, you experience eyestrain and discomfort while viewing the DSM.
- Erroneous sensor model information. Inaccurate sensor model information creates large differences in parallax between two images comprising a DSM.

As a result of these factors, the DSMs contain an effect referred to as y-parallax. To you, y-parallax introduces discomfort during stereo viewing. Figure 31 displays a stereo model with a considerable amount of y-parallax. Figure 32 displays a stereo model with no y-parallax.

Figure 31: Y-parallax Exists

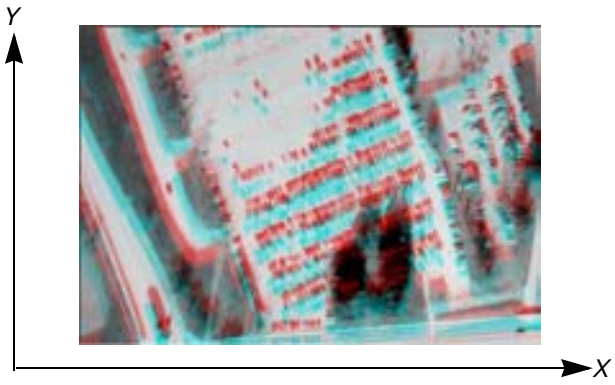
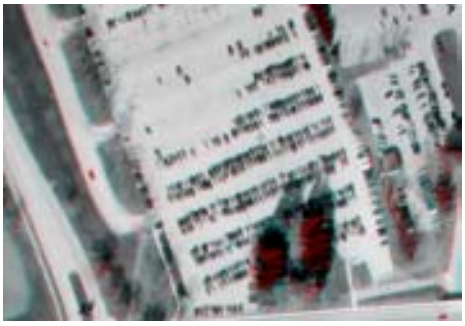


Figure 32: Y-parallax Does Not Exist



To minimize y-parallax, you are required to scale, translate, and rotate the images until a clear and comfortable stereo view is available. Scaling the stereo model involves adjusting the perceived scale of each image comprising a stereopair. This can be achieved by adjusting the scale (that is, relative height) of each image as required. Scaling the stereo model accounts for the differences in altitude as they existed when the left and right photographs were captured.

Translating the stereo model involves adjusting the relative X and Y positions of the left and right images in order to minimize x-parallax and y-parallax. Translating the positions of the left and right images accounts for misaligned images along a flight line. Rotating the left and right images adjusts for the large relative variation in orientation (that is, Omega, Phi, Kappa) for the left and right images.

Scaling, Translation, and Rotation

When viewing a pair of tilted, overlapping photographs in stereo, the left and right images must be continually scaled, translated, and rotated in order to maintain a clear continuous stereo model. Thus, it is your responsibility to adjust y-parallax in order to create a clear stereo view. Once properly oriented, you should notice that the images are oriented parallel to the direction of flight, which was originally used to capture the photography.

When using DSMs created from sensor model information, Stereo Analyst automatically rotates, scales, and translates the imagery to continually provide an optimum stereo view throughout the stereo model. Thus, the y-parallax is automatically accounted for. The process of automatically creating a clear stereo view is referred to as epipolar resampling on the fly. As you roam throughout a DSM, the software accounts and adjusts for y-parallax automatically. Using OpenGL software technology, Stereo Analyst automatically accounts for the tilt and rotation of the two images as they existed when the images were captured.

Figure 33: DSM without Sensor Model Information

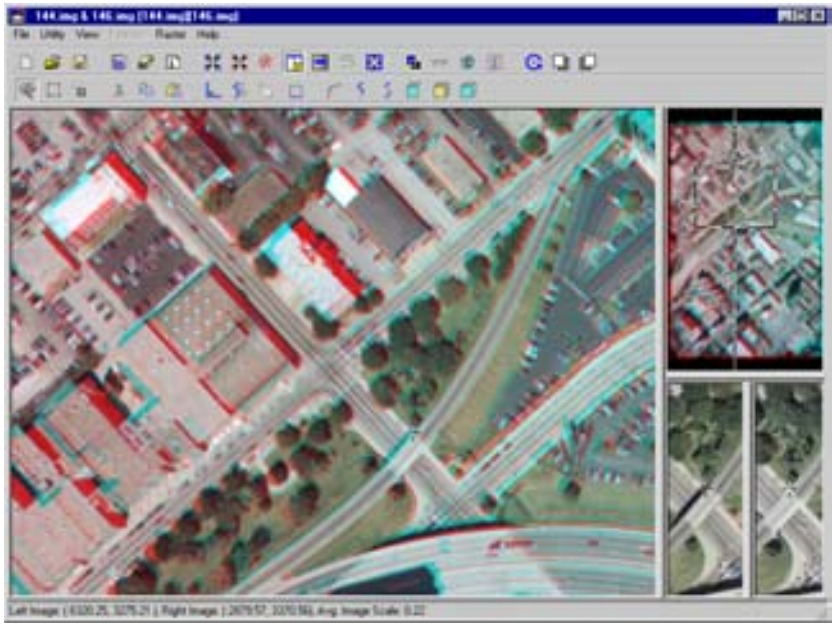


Figure 34: DSM with Sensor Model Information

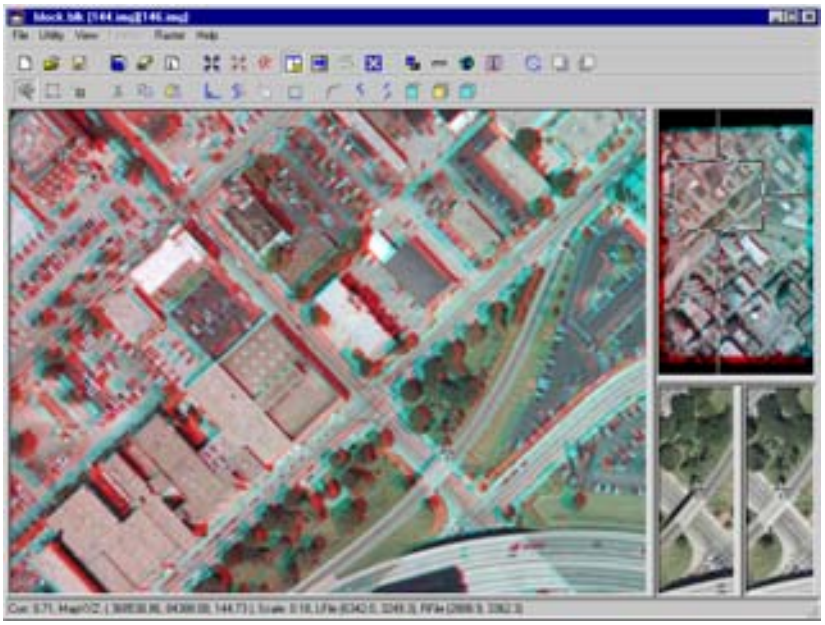


Figure 33 displays a digital stereo model created without sensor model information. Figure 34 displays the use of epipolar resampling techniques for viewing a DSM created with sensor model information.

As a result of using automatic epipolar resampling display techniques, 3D GIS data can be collected to a higher accuracy.

3D Floating Cursor and Feature Collection

In order to accurately collect 3D GIS data from DSMs, a 3D floating cursor must be adjusted so that it rests on the feature being collected. For example, if a road is being collected, the elevation of the 3D floating cursor must be adjusted so that the floating cursor rests on the surface of the road. In this case, the elevation of the road and the 3D floating cursor would be the same.

A 3D floating cursor consists of a cursor displayed for the left image and an independent cursor displayed for the right image of a stereopair. The independent left and right image cursors define the exact image positions of a feature on the images defining a stereopair. It is referred to as a 3D floating cursor since the cursor commonly floats above, below, or on a feature while viewing in stereo. The 3D floating cursor is the primary measuring mark used in Stereo Analyst to collect and measure accurate 3D geographic information.

To collect 3D GIS data in Stereo Analyst, the location of the cursor on the left image must correspond to the location of the cursor on the right image. Using Stereo Analyst, the two cursors that comprise the 3D floating cursor are adjusted simultaneously so that they fuse into one floating cursor that is located in 3D space on the feature being collected or measured.

The elevation of the 3D floating cursor can be adjusted as a function of x-parallax. Since the x-parallax contained within a 3D DSM varies as a function of elevation, the x-parallax of the cursor must be adjusted so that the elevation of the cursor is equivalent to the elevation of the feature being collected. When these two variables are equivalent, the 3D floating cursor should rest on the surface of the feature being collected.

Stereo Analyst uses an approach referred to as automated terrain following to automatically adjust the x-parallax of the 3D floating cursor. This approach uses digital image correlation techniques to determine the image coordinate positions of a feature appearing on the left and right images of the stereopair.

During 3D feature collection, the elevation of the 3D floating cursor must be continually adjusted so that the floating cursor rests on the surface of the feature being collected.

3D Information from Stereo Models

In order to interpret and collect 3D information directly from imagery, at least two overlapping images taken from different perspectives are required. When using aerial photography, the photography is captured from two different camera exposure stations located along the direction of flight. As a result, a strip of overlapping images is captured. The amount of overlap varies according to distance between the two camera exposure stations. A greater distance between photographic exposure separations results in less overlap. A smaller photographic exposure separation results in greater overlap. Sixty percent overlap is the optimum overlap between the left and right photographs or images comprising a stereopair.

For an illustration of overlap, see Figure 12.

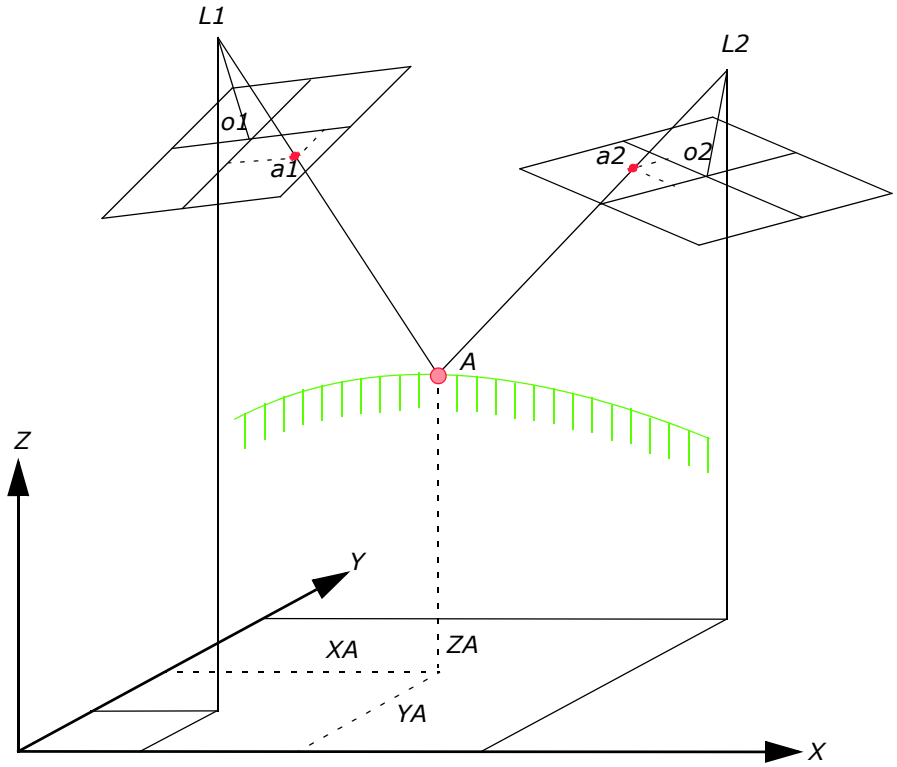
In order to collect 3D information from a stereopair, the following input information is required:

- position of each image comprising a stereopair (that is, X, Y, and Z referenced to a ground coordinate system),
- the attitude, or orientation of each image comprising a stereopair, which is defined by three angles: Omega, Phi, and Kappa, and
- camera calibration information (that is, focal length, principal point).

This information is collectively referred to as sensor model information. Sensor model information is determined using bundle block triangulation techniques. When sensor model information is applied to a stereopair, a DSM can be created.

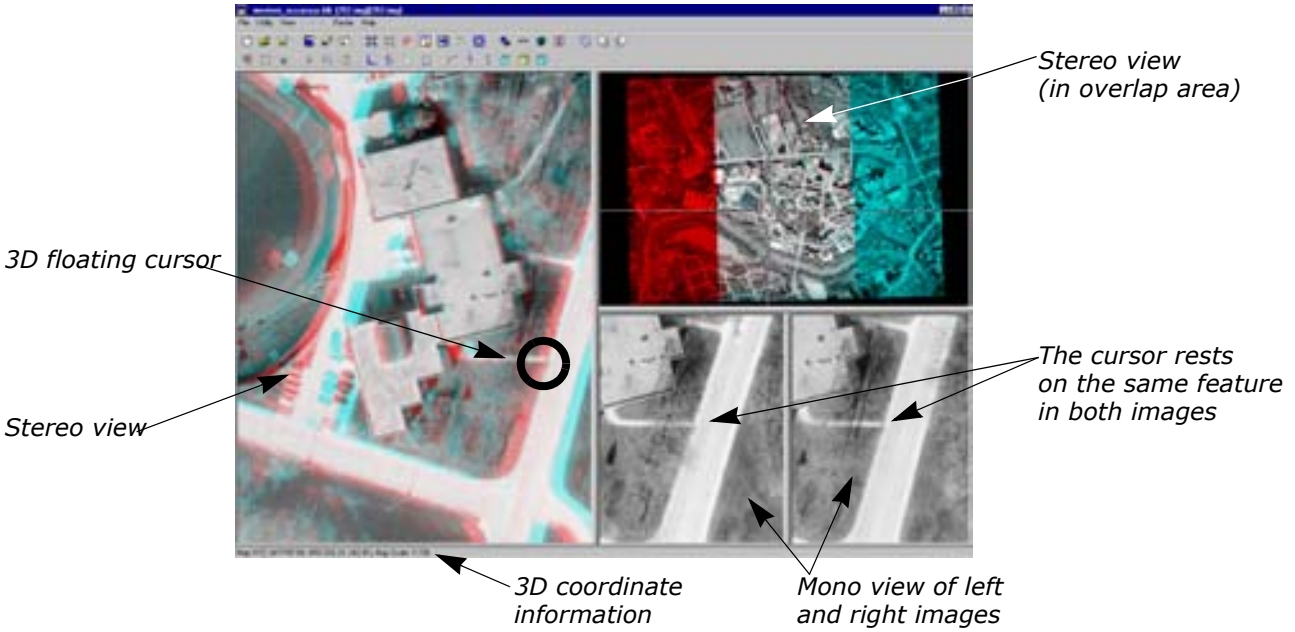
Using 3D space intersection techniques, 3D coordinate information can be derived from a stereopair. Figure 35 illustrates the use of space intersection techniques for the collection of 3D point information from a stereopair. 3D coordinate information can be derived from two overlapping images when sensor model information is known.

Figure 35: Space Intersection



In Figure 35, L_1 and L_2 represent the position and orientation information associated with the left and right images, respectively. Once the 3D floating cursor has been adjusted so that it rests on the ground, the image positions of ground point A on the left and right images are known. In order to obtain accurate 3D coordinate information, it is important that the 3D floating cursor rests on the feature of interest. If the 3D floating cursor rests on the feature of interest, the corresponding image position on the left and right images reflects the same feature.

Figure 36: Stereo Model in Stereo and Mono



If the 3D floating cursor does not rest on the feature of interest, the resulting image positions of the feature on the left and right image are incorrect. Since the image position information is used in conjunction with the sensor model information to calculate 3D coordinate information, it is important that the image positions of the feature be geographically accurate.

Next

Now that you have learned about 3D imaging, photogrammetry, and stereo viewing, you are ready to start the tour guides. They are contained in the next section.

Tour Guides

Creating a Nonoriented DSM

Introduction

Using two overlapping aerial photographs or images, a 3D stereo view can be created. This is achieved by superimposing the overlapping portion of the two photographs. The process of manually orienting two overlapping photographs has been extensively used with airphoto interpretation applications involving a stereoscope. The two overlapping photographs are rotated, scaled, and translated until a clear and optimum 3D stereo view has been achieved. This process is referred to as removing parallax.

Stereo Analyst extends the use of overlapping photography for the interpretation, visualization, and collection of geographic information. Using digitally scanned photographs, Stereo Analyst allows for the rotation, scaling, and translation of overlapping images for the creation of a clear 3D DSM.

Once a DSM has been created, the following are some of the geographic characteristics that can be determined using airphoto interpretation techniques in Stereo Analyst: land use, land cover, tree type, bedrock type, landform type, soil texture, site drainage conditions, susceptibility to flooding, depth of unconsolidated materials over bedrock, and slope of land surface.

This tour guide leads you through the process of using Stereo Analyst to create a clear 3D stereo view for airphoto interpretation applications. Specifically, the steps you are going to execute in this example include:

- Select a mono image that represents the left image comprising a DSM.
- Adjust the display resolution.
- Apply Quick Menu options.
- Select a second image for stereo that represents the right image comprising a DSM.
- Orient and rotate the images.
- Adjust parallax.
- Position the 3D floating cursor.
- Adjust cursor elevation.
- Save the DSM.
- Open the new DSM.

The data you are going to use in this example is of Los Angeles, California. The data is continuous 3-band data with an approximate ground resolution of 0.55 meters. The scale of photography is 1:24,000. The images you use in this example do not have a map projection associated with them; therefore, the DSM you create is nonoriented.

NOTE: The data and imagery used in this tour guide are courtesy of HJW & Associates, Inc., Oakland, California.

Approximate completion time for this tour guide is 1 hour.

You must have both Stereo Analyst and the example files installed to complete this tour guide.

Getting Started

NOTE: This tour guide was created in color anaglyph mode. If you want your results to match those in this tour guide, set your stereo mode to color anaglyph by selecting **Utility -> Stereo Analyst Options -> Stereo Mode -> Stereo Mode -> Color Anaglyph Stereo**.

Launch Stereo Analyst

To launch Stereo Analyst, you first launch ERDAS IMAGINE. You may select **ERDAS IMAGINE** from the **Start -> Programs** menu, or you may have created a shortcut to ERDAS IMAGINE on your desktop.

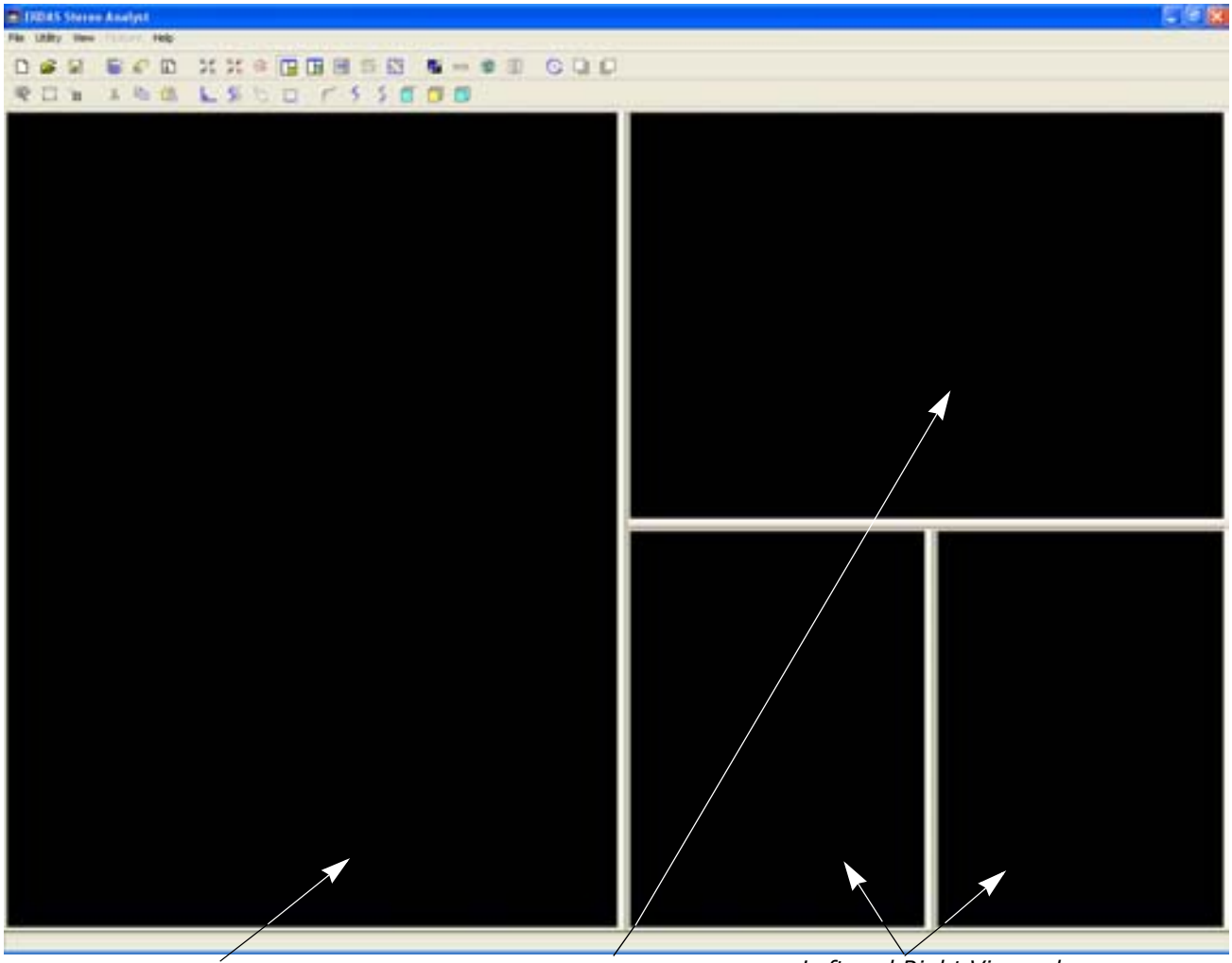
1. Launch ERDAS IMAGINE.
2. Click the Stereo Analyst icon on the ERDAS IMAGINE toolbar.

Optionally, you can use Microsoft Explorer to navigate to the following directory: **IMAGINE\Bin\NTx86**. *Double-click* **hifi.exe** *to start Stereo Analyst. You can create a shortcut to the executable on your desktop if you wish.*

3. Click **Stereo Analyst** on the Stereo Analyst dialog.

Adjust the Digital Stereoscope Workspace

The Digital Stereoscope Workspace opens.



1. Move your mouse over the bar between the Main View and the OverView, and Left and Right Views. It becomes a double-headed arrow.
2. Drag the bar to the right and/or left to resize the Main View, OverView, Left and Right Views.

Load the LA Data

The data you are going to use for this tour guide is not located in the examples directory. Rather, it is included on a data CD that comes with the Stereo Analyst installation packet. To load this data, follow the instructions below.

1. Insert the Stereo Analyst data CD into the CD-ROM drive.
2. Open Windows Explorer.

3. Select the files **la_left.img** and **la_right.img** and copy them to a directory on your local drive where you have write permission.

4. Ensure that the files are not read-only by right clicking to select **Properties**, then making sure that the **Read-only Attribute** is not checked.

Open the Left Image

A nonoriented DSM provides a 3D representation when viewed in stereo, but does not provide absolute real-world geographic coordinates. The images comprising a nonoriented DSM have not been geometrically oriented and aligned using accurate sensor model information.

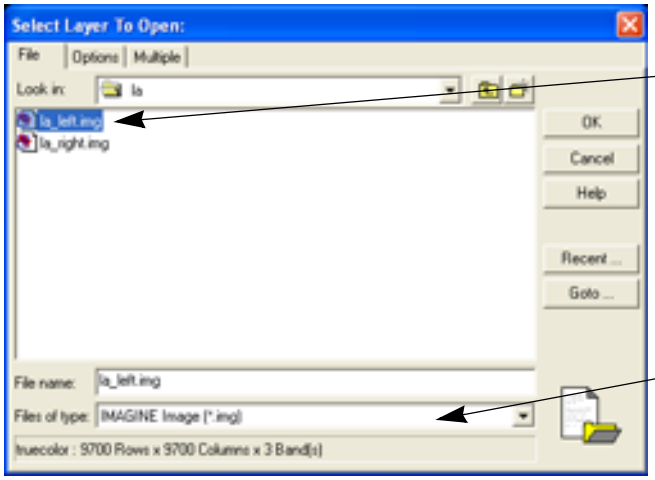
As a result, you must rotate, scale, and adjust the images while viewing different portions of the nonoriented DSM. The two images comprising the nonoriented DSM must be adjusted at various parts of the image since elevation varies throughout the area imaged on the photographs.

As elevation changes, so does parallax. Therefore, you must compensate for the variations in parallax to ensure that a clear and optimum 3D display is provided. A clear and optimum 3D stereo display is provided when y-parallax has been removed and the amount of x-parallax is sufficient for conveying elevation changes within a local geographic area of interest.

If the sensor model information associated with the two images is available, Stereo Analyst automatically rotates, scales, and adjusts the images while viewing the DSM. DSMs created using sensor model information are also referred to as oriented DSMs. Real-world geographic coordinates can be collected from oriented DSMs.

1. From the toolbar of the empty Digital Stereoscope Workspace, click the Open icon .

   The Select Layer To Open dialog opens. Here, you select the type of file you want to open in the Digital Stereoscope Workspace.



2. Click the **Files of type** dropdown list and select **IMAGINE Image (*.img)**.

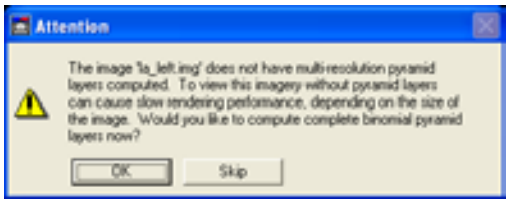
   Other image types can also be used for the creation of DSMs. Stereo Analyst directly supports the use of TIF, JPEG, Generic Binary, Raw Binary and other commonly used image formats.

   Using DLLs, the various image formats no longer need to be imported for use within Stereo Analyst. Simply select the image format of choice from the **Files of type** dropdown list, and use the imagery in Stereo Analyst for the creation of DSMs.

3. Navigate to the directory where you saved the files, then select the file named **la_left.img**.

4. Click **OK** in the Select Layer To Open dialog.

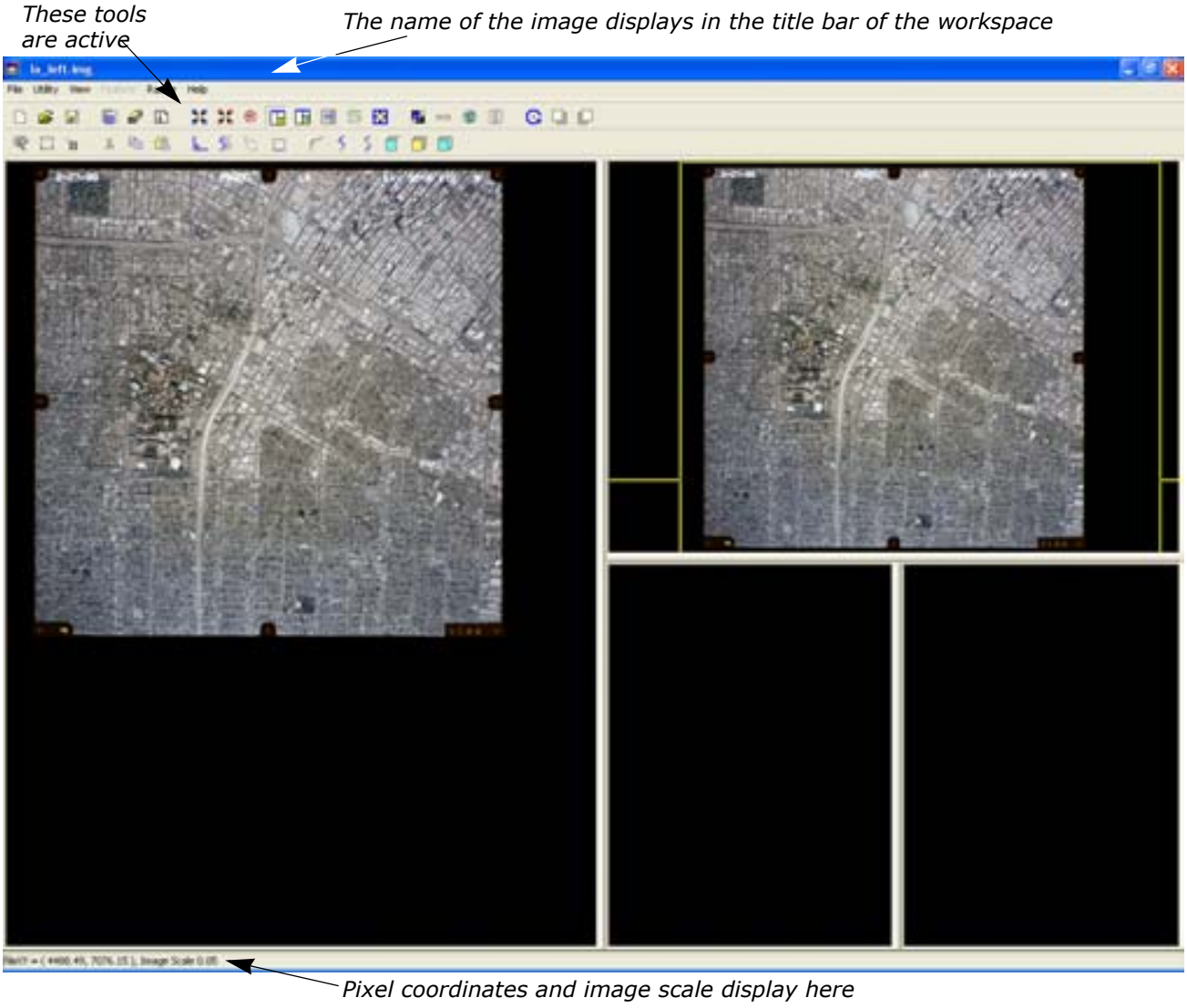
   As Stereo Analyst opens the file, pyramid layers are optionally generated. Pyramid layers allow the image to display faster in the Main View at whatever resolution you choose. Pyramid layers are layers of the image data that are successively reduced by a power of two.



5. Click **OK** in the dialog prompting you to create pyramid layers.

The file of Los Angeles, **la_left.img**, displays in the Digital Stereoscope Workspace.

NOTE: The screen captures provided in this tour guide were generated in the Color Anaglyph Stereo mode. If you are running Stereo Analyst with Quad Buffered Stereo configuration, your images appear in natural color.



Adjust Display Resolution

Now that you have an image displayed in the Main View, you can manipulate its display. Your mouse allows you to roam and zoom throughout the image. Next, you can practice techniques.

Zoom

NOTE: This exercise is easier to complete if the Digital Stereoscope Workspace is enlarged to fill your display area.

1. In the Main View, position your cursor over the stadium in the left-hand portion of the image (indicated with a red circle in the following picture).

2. Hold down the wheel and push the mouse forward and away from you.

If your mouse is not equipped with a wheel, use the middle mouse button, or the Control key and the left mouse button simultaneously, while moving the mouse forward and away from you.

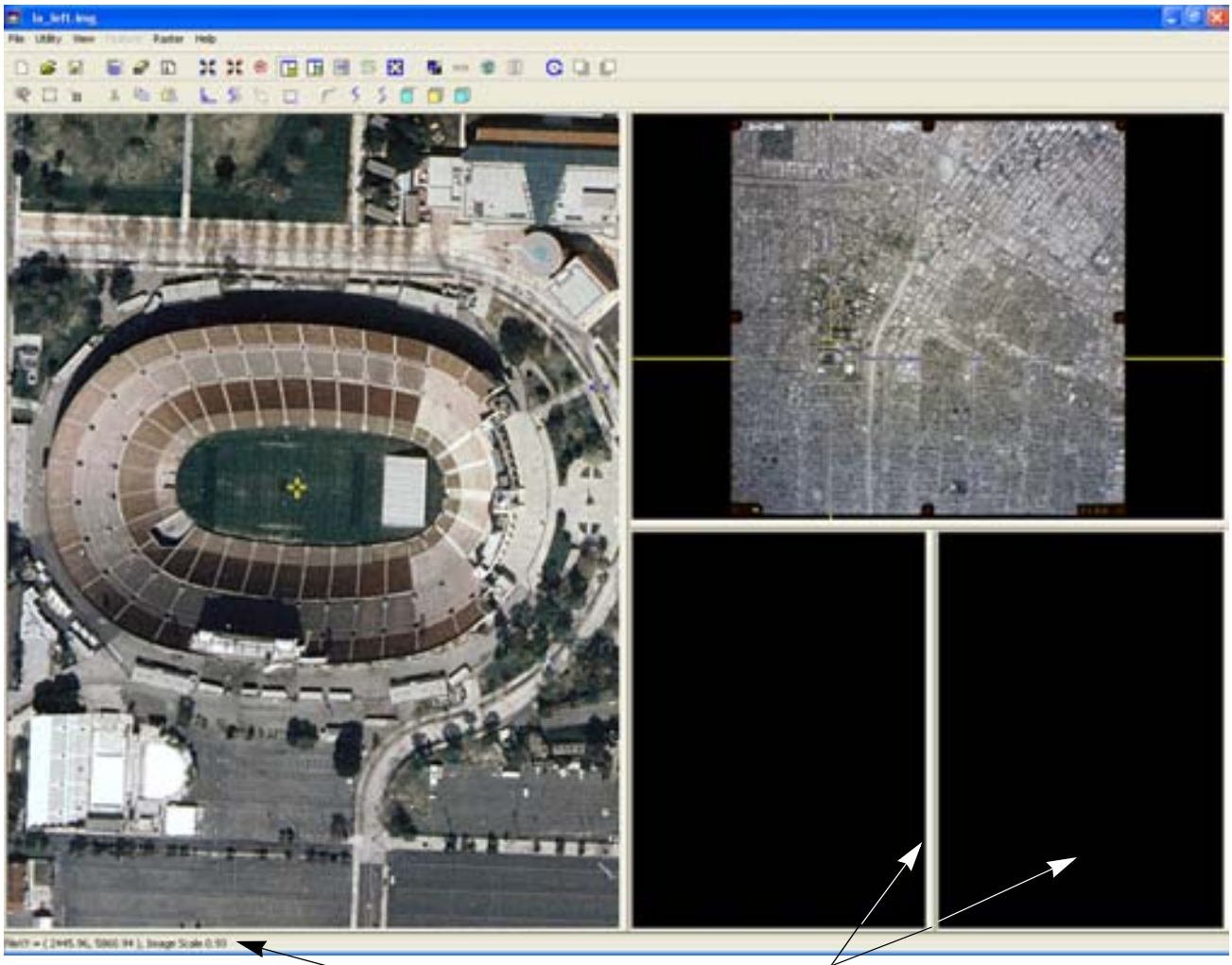
3. If necessary, click and hold the left mouse button, then drag the image to position the stadium in the middle of the Main View.

4. Continue to move the mouse until the stadium appears at a resolution you can view comfortably. Note that the image scale displays in the status area of the Digital Stereoscope Workspace.

What is image scale?

An image scale (SI) of 1 indicates that the image is being viewed at its original resolution (that is, one image pixel equals one screen pixel). An image scale value greater than 1 indicates that the image is being viewed at a magnification factor larger than the original resolution.

For example, an image scale of 2 indicates that the image is being displayed at 2 times the original image resolution. An image scale less than 1 indicates that the image is being viewed at a resolution less than the original image resolution. For example, an image scale of 0.5 indicates that the image is being displayed at half of the original image resolution.



Scale displays here, in the status area

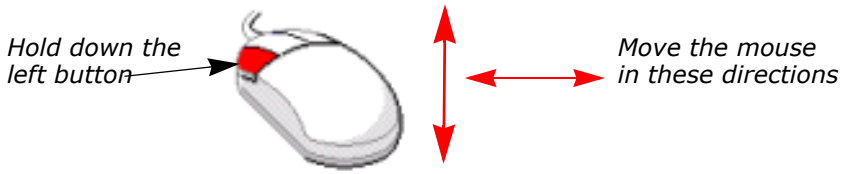
Since you are only viewing one image, the Left and Right Views are empty

Roam

Now that you have sufficiently zoomed into the image so that you can see geographic details, you can roam about the image to see other areas.

The status area also displays the row and column image pixel coordinates of the cursor. When an oriented DSM displays, the 3D X, Y, and Z coordinates of the cursor are displayed. When two images comprising a nonoriented DSM are displayed, the corresponding pixel coordinates of the cursor for the left and right images are displayed.

1. In the Main View, click and hold down the left mouse button and move the mouse forward and backward, left and right to see other portions of the image.



2. Once you find an area you are interested in, you may choose to zoom in.

3. Continue to roam and zoom throughout the image to familiarize yourself with the mouse motions.

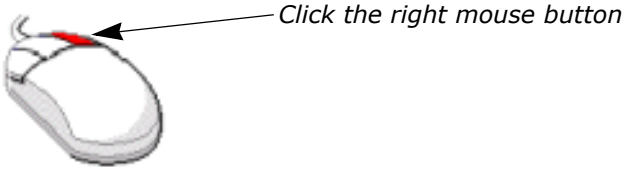
You can also roam throughout the image by selecting the crosshair in the OverView and moving it.

Check Quick Menu Options

Stereo Analyst has tools that allow you to change the brightness and contrast of images as they are displayed in the Digital Stereoscope Workspace.

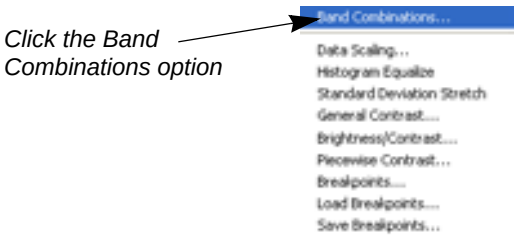
1. Navigate to an area that interests you.
2. Zoom in to see the details of the area.

3. Click the right mouse button.



The **Quick Menu** opens.

4. Move your mouse over the **Left Image** option on the **Quick Menu**. The options you can apply to the Left Image display.

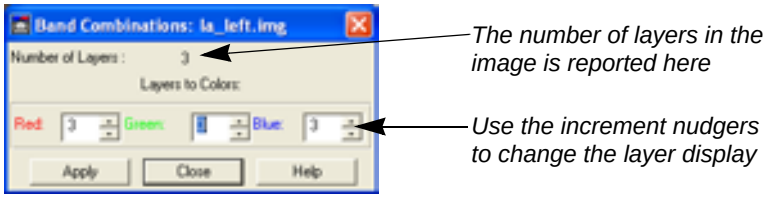


These options are also available under **Raster -> Right Image** *when you have a right image displayed in the workspace.*

Check Band Combinations

1. Click on the first option, **Band Combinations**.

   The following dialog opens.



   If you find it easier to work with monochrome images, you can use this dialog to make changes.

2. Use the increment nudgers to change the layers assigned to **Red** and **Green** to **3**.

3. Click **Apply**.

   The image redisplays in monochrome.

4. Change **Red** layer back to **1** and the **Green** layer back to **2**, then click **Apply**.

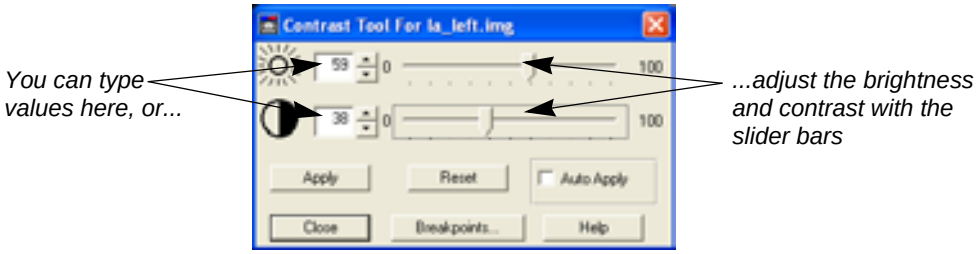
   The image displays with its default layer to color assignments.

5. Click the **Close** button on the Band Combinations dialog.

Change Brightness and Contrast

1. Right-click to access the **Quick Menu** again.
2. Move your mouse over **Left Image**, then select **Brightness/Contrast**.

   The Contrast Tool dialog opens.



3. Adjust the brightness and contrast meters by clicking, holding, and moving the sliding bars right or left, then click **Apply**.

   Depending on the settings you choose, the image may appear better or worse to you in the Main View.

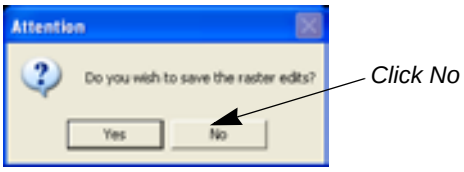
4. Return the image to its default display by clicking **Reset**, then click **Apply**.
5. Click **Close** in the Contrast Tool dialog.

Add a Second Image

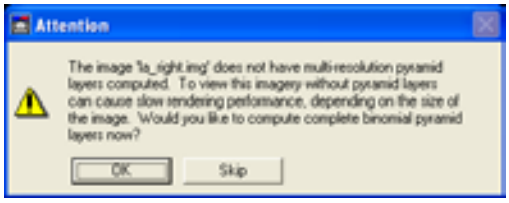
For the remainder of the tour guide, you need either red/blue anaglyph glasses or stereo glasses that work in conjunction with an emitter.

Now, you can add a second image to the Main View so that you can view the overlap portion of the two images in stereo.

1. From the **File** menu of the Digital Stereoscope Workspace, select **Open -> Add a Second Image for Stereo**.
2. In the Select Layer To Open dialog, navigate to the directory where you loaded the images and select the image **la_right.img**.
3. Click **OK** in the Select Layer To Open dialog.
4. If you receive the following message prompting you to save raster edits, click **No** in the dialog.



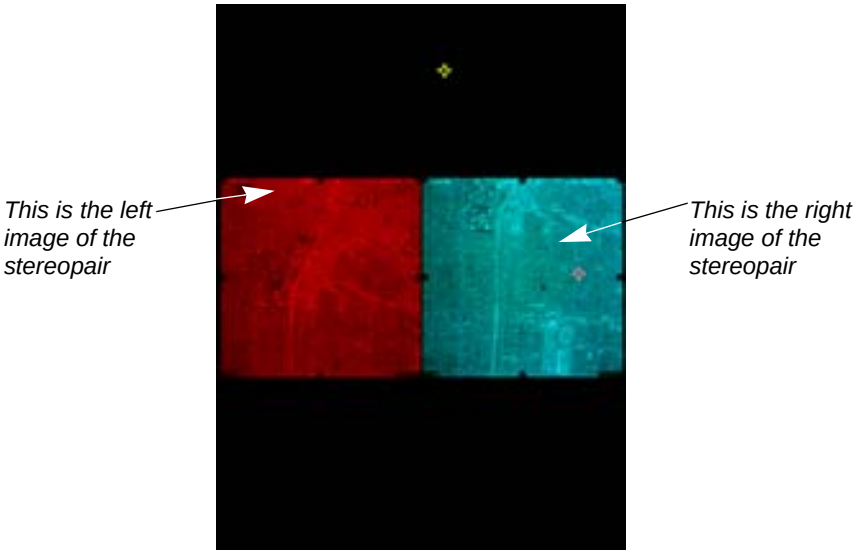
5. Click **OK** to generate pyramid layers for this image too.



If you have not viewed an image before, you are prompted to create pyramid layers. Pyramid layers of the image, **la_right.img**, make it display faster in the Workspace at any resolution.

NOTE: The following picture displays the images in Color Anaglyph Stereo. That is so you can view the images in this book using red/blue glasses. Your images will appear different if you have your stereo mode set to Quad Buffered Stereo.

You notice that the initial image, **la_left.img**, no longer displays as a typical raster red, green, blue image. This is due to the default settings of Stereo Analyst. Once two mono images are displayed in the Digital Stereoscope Workspace, Stereo Analyst uses the **Stereo Mode** display you specify in the **Options** dialog, which, in the case of this tour guide, is Color Anaglyph Stereo.



In order to view stereo images in the Main View, your eye base (the distance between your left eye and your right eye) must be parallel to the photographic base of the two photographs. The photographic base is the distance between the left image camera exposure station and the right image camera exposure station. If your eye base is not parallel to your photographic base, you are not able to perceive the DSM in 3D.

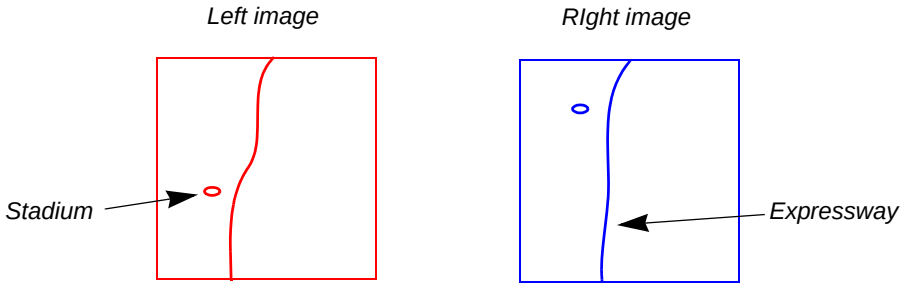
The two images currently displayed in the Main View are not parallel to your eye base. For this reason, the images must first be rotated so that they are parallel to your eye base.

Adjust and Rotate the Display

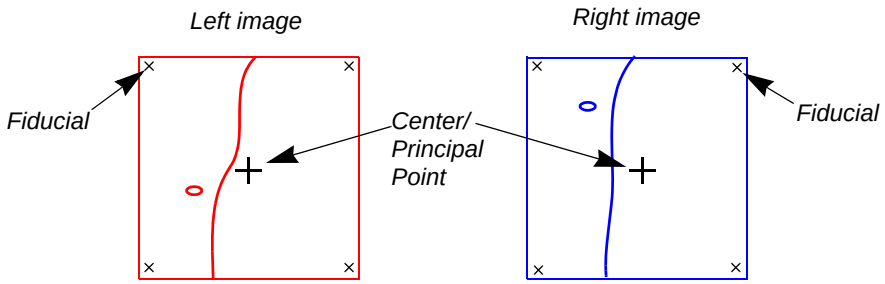
You may be asking yourself: How do I know if the images are properly oriented for stereo viewing? The following steps can be used to determine the proper orientation of any two photographs for stereo viewing.

Examine the Images

NOTE: For the purposes of this section, simple illustrations are used to represent the left and right images of the stereopair.



1. Visually identify the center point (principal point) of each image.

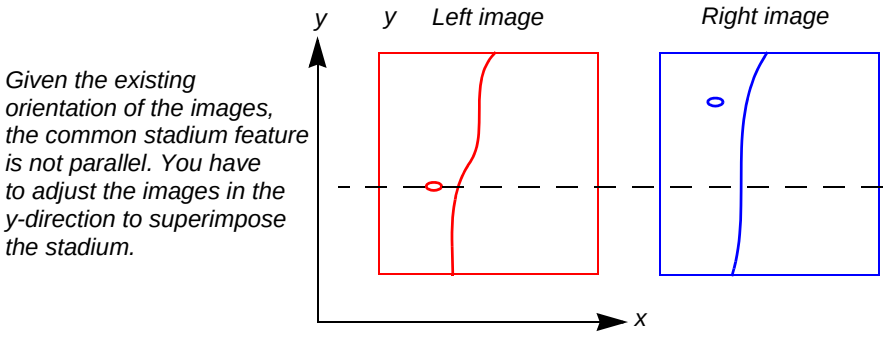


The center point of the image is also referred to as the principal point. The center point of each image can be visually identified by intersecting the corner points (that is, fiducials) of the images. When you visually record the center point of each image, you note whether it is a house, building, road intersection, tree, etc.

2. Visually identify the feature located at the center point in the left image, **la_left.img**.

3. Visually identify the same feature on the right image, **la_right.img**.

   The common feature on the left image should be approximately parallel to the same feature on the right image. Thus, the same feature on the left and right images should be separated only along the x-direction and not the y-direction. If the common feature is not parallel on the left and right images, the images must be rotated. Consult the following diagram.

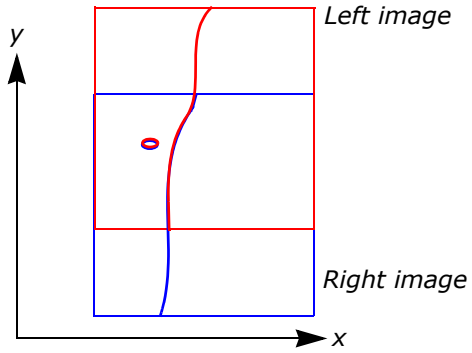


Orient the Images

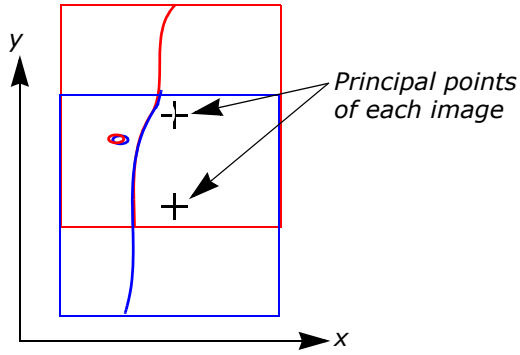
Now that you have determined that these images are not properly oriented for stereo viewing, you may be asking yourself: How do I properly orient the two photographs for stereo viewing? You can use the Left Buffer icon to manually superimpose the feature (in this case, the stadium) identified on the left image with the corresponding feature on the right image.

1. Click the Left Buffer icon on the Digital Stereoscope Workspace toolbar.

2. Click and hold to select the left image, **la_left.img** (the red image), and drag it over the right image so that the common feature overlaps, as depicted in the following illustration.

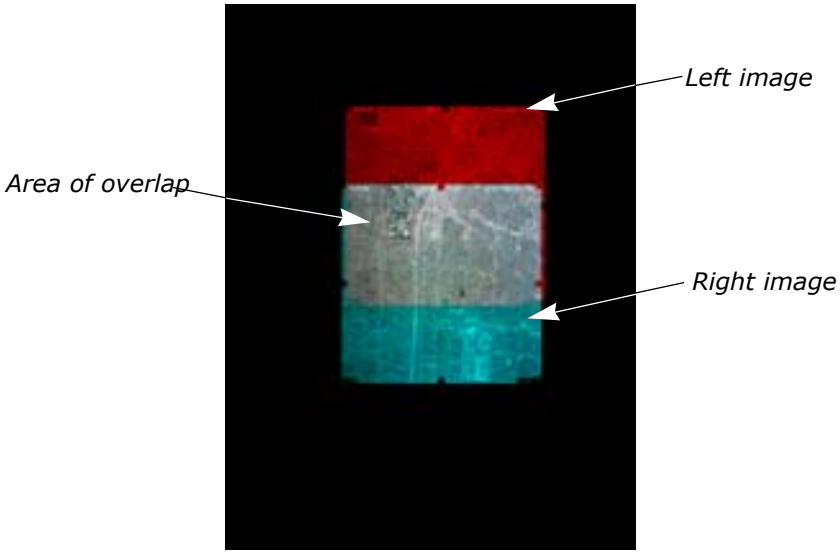


3. Notice that the principal point on the left and right images is separated along the y-direction. This is incorrect for stereo viewing. Consult the following illustration.



In order to obtain a 3D stereo view, the principal point on the left and right images must be separated along the x-direction. If the principal points are not separated along the x-direction, the images must be rotated.

If you have followed the steps correctly to this point, your stereopair should look similar to the following illustration.



4. Click the Left Buffer icon again to deselect it.

5. Click, hold, and drag the stereopair until it is positioned in the middle of the Main View.

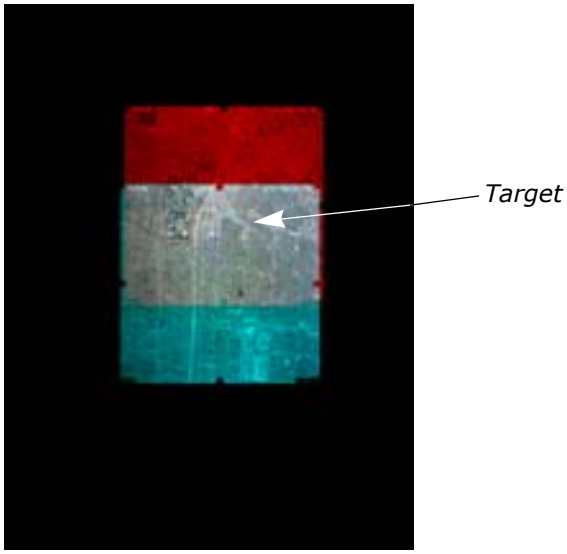
Rotate the Images

When you rotate images, you turn them in incremental degrees to the right (clockwise) and left (counterclockwise). To see this more clearly, you can zoom out so that the extent of both images is visible in the Main View.

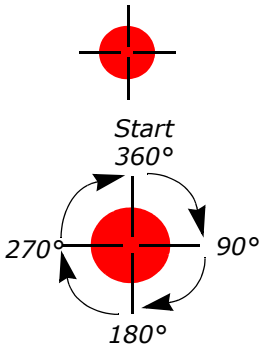
1. Click the Rotate Tool icon .

2. Move your mouse into the Main View, and double-click in the center portion of the overlap area, which appears to be gray in Color Anaglyph mode.

   A target appears in the overlap area:



3. Click and hold the left mouse button inside the target (see the following illustration), and move the mouse horizontally to the right to create an axis. Extend the axis until the cursor is located outside of the image area.

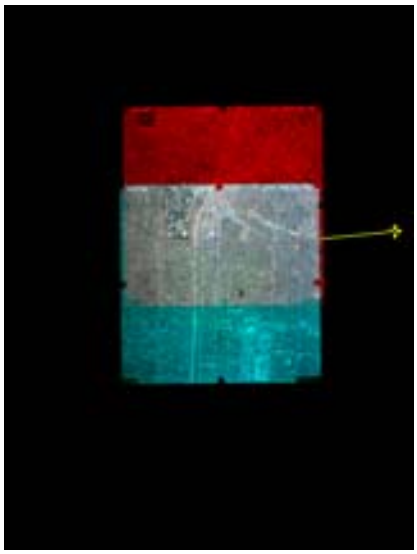


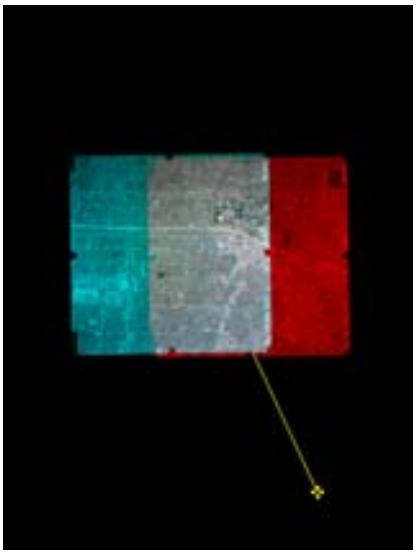
For the purpose of illustration, the area inside the target is red. Click anywhere inside the red area to create an axis.

Rotate the image in the Main View relative to the target. Clockwise, the angles are 90, 180, 279, and 360 degrees.

The axis originates from the center of the target to a position you set. A longer line axis provides greater flexibility in rotating the images. A shorter axis provides greater sensitivity to the rotation process. It is recommended that a longer axis be used for rotating the images. To obtain a longer axis, move the cursor farther away from the center point of the target.

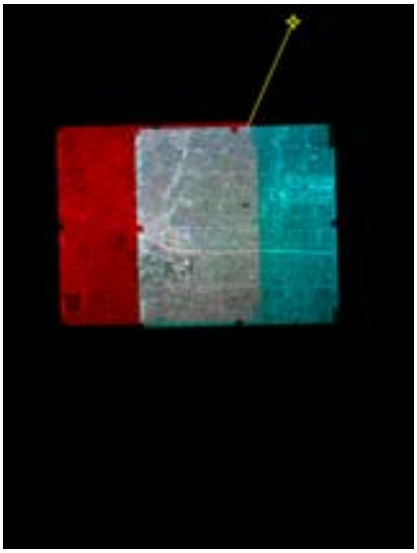
4. Move the mouse 90 degrees clockwise.





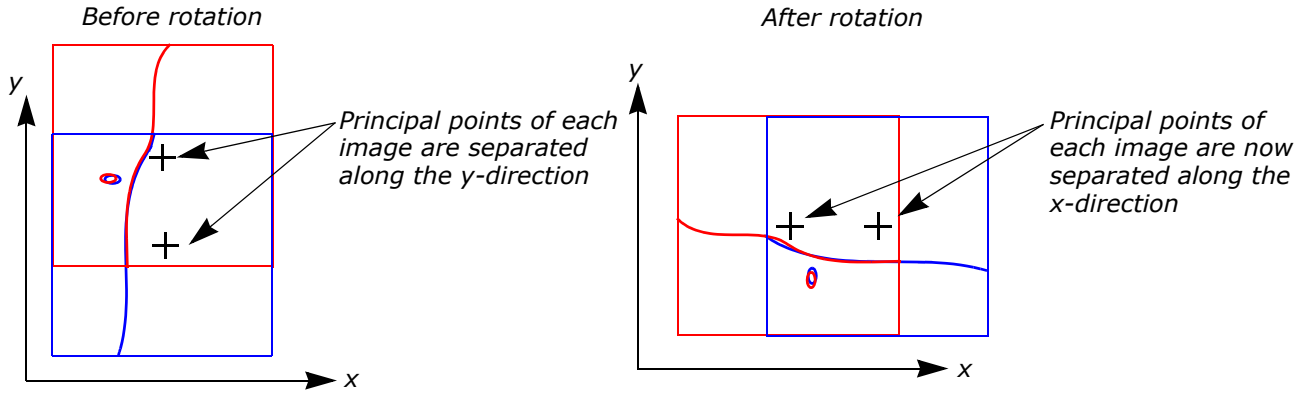
NOTE: Notice the position of the stadium with the clockwise rotation.

5. Move the mouse ann additional 180 degrees clockwise.



6. When you are finished, click once to remove the axis, then click the Rotate Tool icon again to deselect it.

   Once the photographs have been properly oriented, a clear 3D stereo view displays. Adjusting the images along the x-direction modifies the vertical exaggeration of the 3D DSM. Consult the simple illustration again to see that, with the rotation of the images, the principal points are now separated along the x-direction.



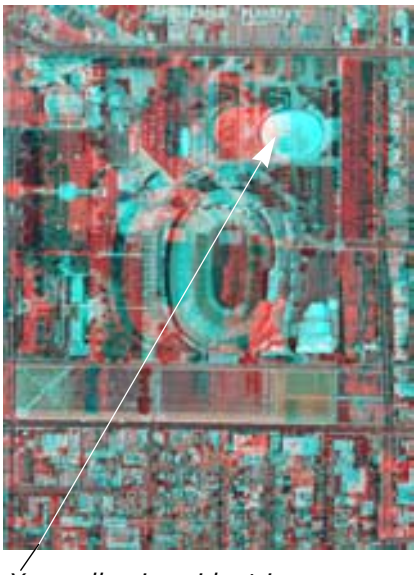
Adjust X-parallax

To adjust the depth or vertical exaggeration of the images, you must adjust the amount of x-parallax. Adjusting the x-parallax of the images provides a clear and optimum 3D DSM for viewing and interpreting information. If the area of interest experiences too much vertical exaggeration, interpreting geographic information becomes increasingly difficult and inaccurate. If the area of interest experiences minimal vertical exaggeration, slight variations in elevation cannot be interpreted. In Stereo Analyst, you can reduce the amount of x-parallax in an image by using a combination of the mouse and the **X** key on your keyboard.

For more information, please refer to "Adjusting X Parallax" on page 103.

1. Position the cursor over the stadium, then press and hold the wheel while moving the mouse away from you to zoom in.

2. If necessary, use the Left Buffer icon and adjust the position of the image to improve the overlap of the images. Be sure to deselect it when you are finished adjusting the left image of the stereopair. Be sure to deselect the icon when you are finished.



X-parallax is evident in this portion of the image—the building features do not overlap

X-parallax has been adjusted

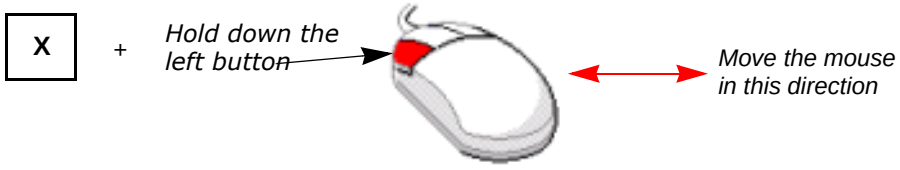
NOTE: In this portion of the image, the X-parallax has been exaggerated for the purposes of this tour guide.

Notice that the left and right images (red and blue, respectively) are not aligning properly. This is especially apparent in the parking area, where the sidewalks and trees are not on top of one another: one appears to be a ghost image of the other.

Once the left and right images, and hence the sidewalks, are aligned, you can see in stereo. Again, keep in mind that your perception may differ depending on the mode in which you are viewing the images: Quad Buffered Stereo or Color Anaglyph Stereo.

3. Hold down the **X** key on your keyboard while you simultaneously hold down the left mouse button.

4. Move the mouse to the left and/or right until the same features overlap.



5. Experiment with the x-parallax by over-adjusting to see the features separate again.

6. Return the images to their aligned positions.

Once the x-parallax has been properly adjusted, you can comfortably perceive the stereopair in 3D.

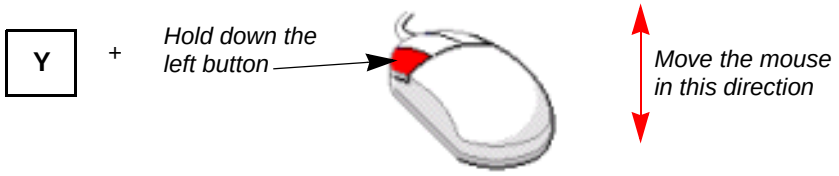
Now that you have learned how to adjust the x-parallax of an image, you can use some other methods to improve the display of the stereopair in the Main View.

Adjust Y-parallax

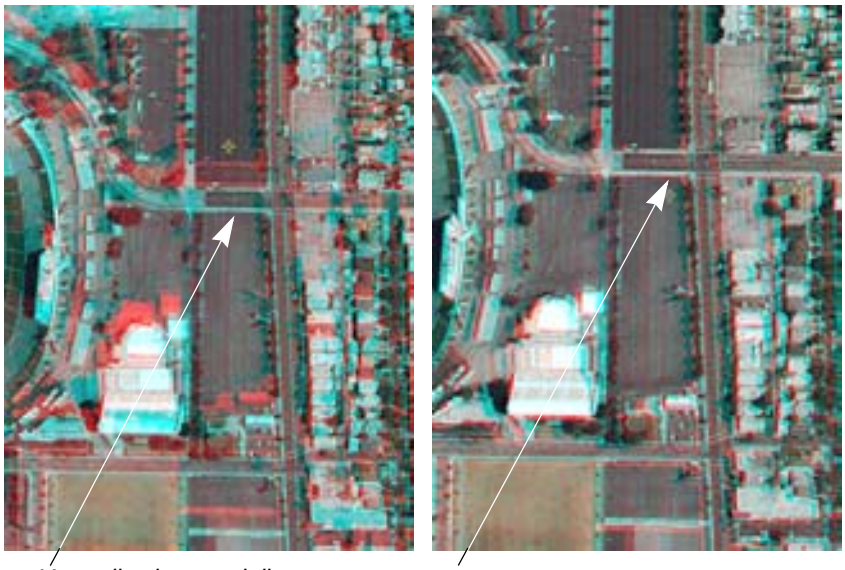
At the same location you adjusted x-parallax, you can also experiment with adjusting y-parallax. Typically, y-parallax does not need as much adjustment as x-parallax.

For more information, please refer to "Adjusting Y-Parallax" on page 104.

1. Hold down the **Y** key on your keyboard while simultaneously holding down the left mouse button.
2. Move the mouse up and down until the same features overlap.



Once you have moved the images sufficiently far apart, you can perceive the y-parallax, as depicted in the following illustration, which has been exaggerated for the purposes of this tour guide.



3. Return the y-parallax to a comfortable viewing perspective.

4. Click the Zoom to Full Extent icon .

   The full DSM displays in the Digital Stereoscope Workspace.

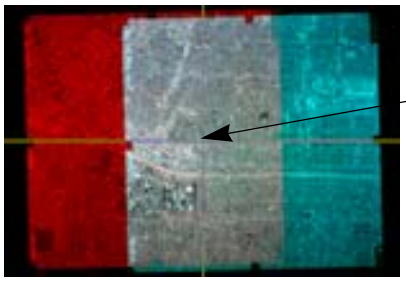
Position the 3D Cursor

In Stereo Analyst, the 3D position of the cursor is very important. Because you may want to collect 3D features, you must be able to position the cursor on the ground, on a rooftop, or some other feature. You can adjust the elevation of the cursor in a number of ways.

For more information about how to position the cursor, please refer to "Cursor Height Adjustment" on page 105.

With the DSM fit in the window, you use the OverView adjust the DSM so that you can see a portion of it that has changes in elevation.

1. Click on the Zoom to 1:1 icon .
2. Click on an edge of the crosshair in the OverView.
3. Hold and drag it to the area of the expressway that runs through the approximate center of the image.



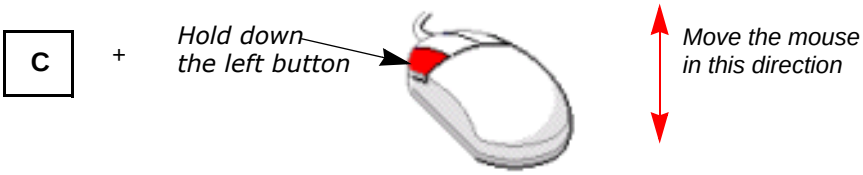
Adjust the display of the DSM in the views by moving the link box

The expressway is constructed in a number of levels.

Three levels are represented in this portion of the expressway, which is a good location for adjusting cursor elevation.

4. Zoom in to see a detailed portion of the expressway with many overpasses.
5. Adjust the x-parallax and y-parallax as necessary.
6. Position the cursor over one of the elevated areas of the expressway.
7. Adjust the elevation of the cursor by rolling the mouse wheel until the cursors converge.

*If you do not have a mouse equipped with a wheel, you can hold the **C** key on the keyboard, as you simultaneously hold the left mouse button. Then, move the mouse forward and away from or backwards and toward you to adjust elevation.*



8. Notice how the cursor appears to float above, at, and below ground level as you adjust it using the mouse. Practice moving the mouse in this way until you can tell the cursor is on the ground.

   NOTE: Remember that you can also check the 3D cursor position by using the Left and Right Views. If the cursor appears to be positioned on the same point in the views, then it is positioned on the feature, as in the illustration below.

In the example that follows, the cursor is positioned on the top overpass of the expressway. You can experiment with this area by placing the cursor on the various levels that make up the expressway.

9. Move to another area of the stereopair, such as the stadium, and practice adjusting the cursor elevation.

Stereo Analyst can maintain the cursor at a specific Z elevation if you wish. This is controlled in the **Options** *dialog, under the* **Cursor Height and Adjustment** *Option Category. In this mode, regardless of where you are in the image, the cursor maintains the same elevation. You can view actual elevations in the window by deselecting this option.*

Practice Using Tools

Now that you know how to adjust x-parallax, y-parallax, and cursor elevation, you can practice using the methods you have learned in other areas of the image. First, you zoom into and out of areas of the image. You can then use the OverView and Left and Right Views to see features.

Zoom Into and Out of the Image

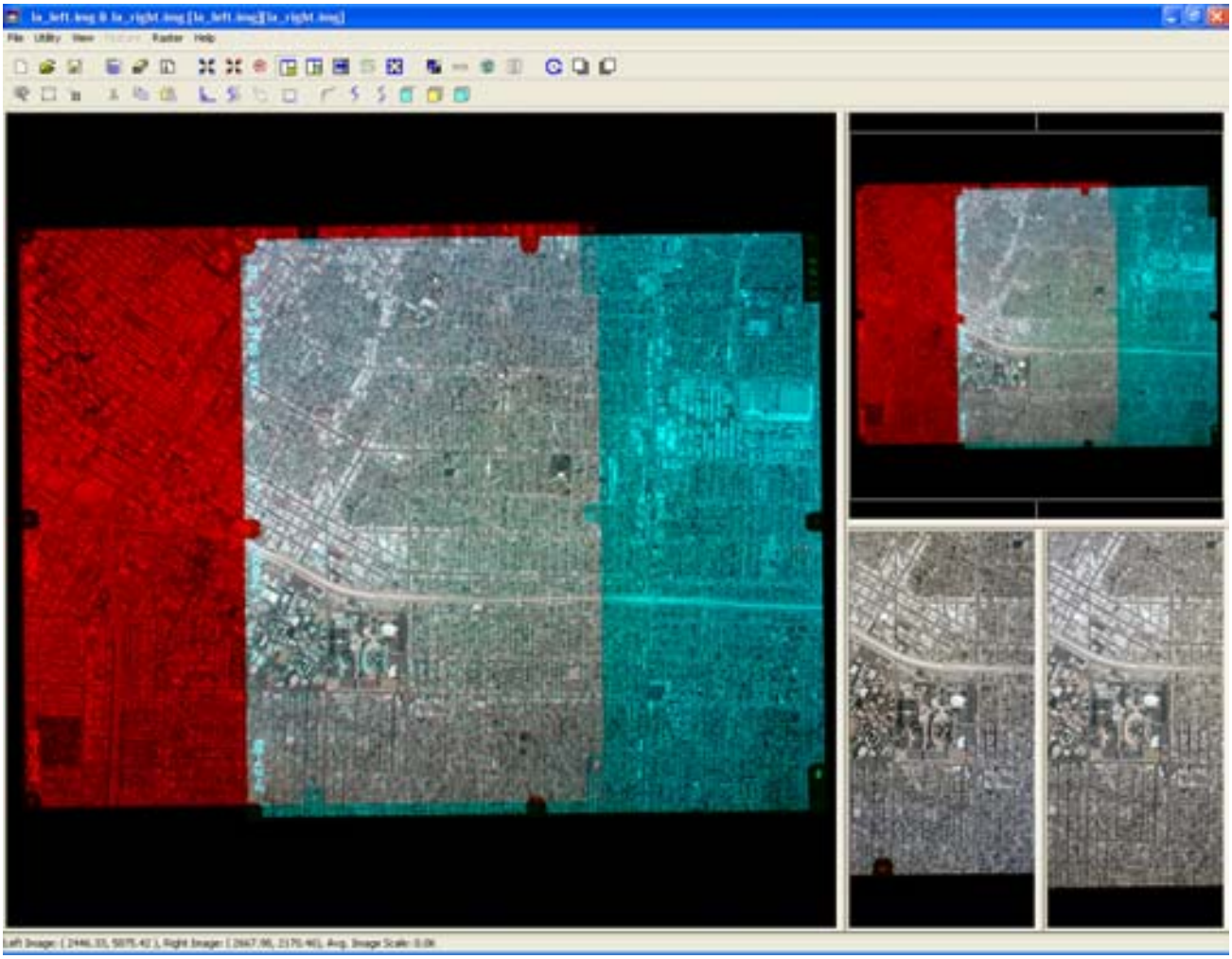
1. Hold down the wheel, and push the mouse away from you (that is, up and down). This motion zooms into a more detailed portion of the stereopair.
2. Continue to zoom in until you can see a sufficiently detailed area.
3. To roam, hold down the left mouse button and drag the stereopair in the window to the right and/or left until you find an area that interests you, such as the following:

4. Zoom out by clicking and holding the wheel, and pull the mouse toward you. You can see a larger portion of the stereopair in the view.
5. Click the 1:1 Resolution icon .

The stereopair displays in the Digital Stereoscope Workspace at a 1:1 resolution (image pixel to screen pixel). Therefore, one image pixel equals one screen pixel.

6. Adjust the x-parallax and the Y-parallax as necessary.

7. Click the view Full Extent icon .



Save the Stereo Model to an Image File

A DSM can be saved as a stereo anaglyph image that can be used in the field or laboratory to conduct airphoto interpretation. Using hardcopy anaglyph stereo prints is useful for interpreting height and geographic information while in the field. Hardcopy anaglyph stereo prints can also be shared with others to convey geographic information.

Saving a DSM records and captures the image contained within the Main View of the Digital Stereoscope Workspace. If the Stereo Mode is Quad Buffered Stereo, the resulting image is saved as Color Anaglyph Stereo.

1. Click **File** menu of the Digital Stereoscope Workspace, select **View to Image**.

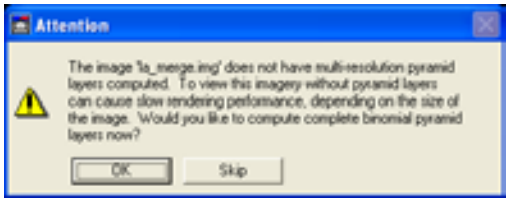
   The View to Image dialog opens.

2. Navigate to a directory in which you have write permission.
3. Click in the **File name** field and type the name **la_merge**, then press Enter on your keyboard. The .img extension is added automatically.
4. Click **OK** in the View to Image dialog.

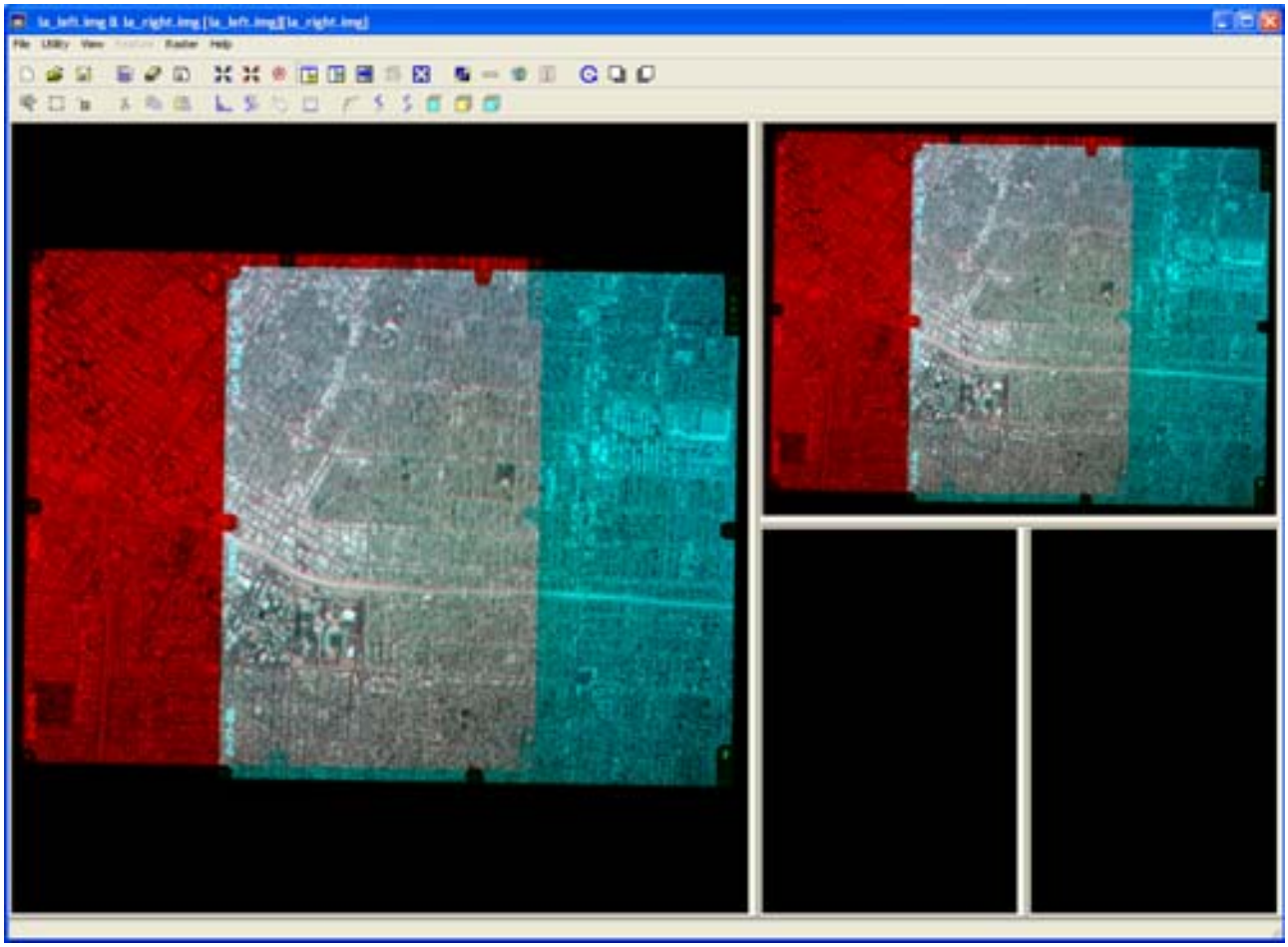
Open the New DSM

You can now open the new DSM in the Digital Stereoscope Workspace.

1. Click the Clear View icon .
2. Click the Open icon .
3. Navigate to the directory in which you saved the DSM, **la_merge.img**.
4. Select the image **la_merge.img**, then click **OK** in the Select Layer To Open dialog.
5. Click **OK** in the dialog prompting you to create pyramid layers.



NOTE: The alert to create pyramid layers only occurs the first time you open the new image in the Digital Stereoscope Workspace. Once pyramid layers are created, they remain with the image in a separate .rrd file.



6. Use the mouse to zoom into and out of the DSM in the Digital Stereoscope Workspace.

   NOTE: Now that the left and right images have been merged into one, you can no longer adjust the x-parallax and the Y-parallax. Therefore, you may wish to zoom into a smaller area of an image before using **View to Image**. *That way, the parallax is properly adjusted for a specific portion of the image.*

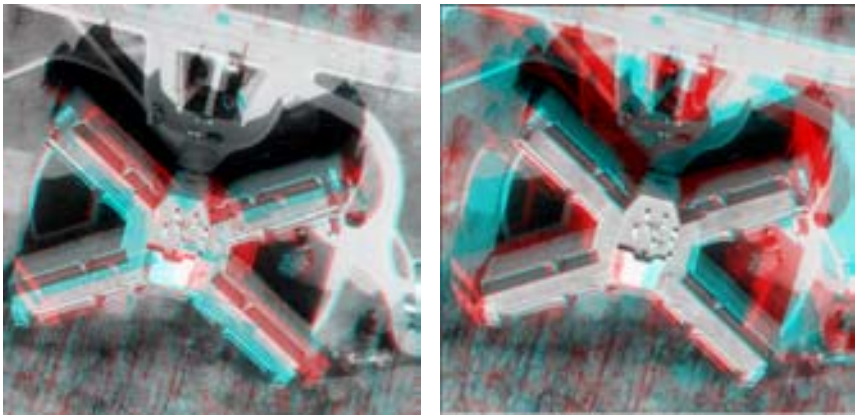
7. Click the Clear View icon .

8. Select **File -> Exit Workspace** to close Stereo Analyst if you wish.

Adjusting X Parallax

X-parallax is a function of elevation. Therefore, as elevation varies throughout the geographic area covered by the image, so does the amount of x-parallax. The following two figures illustrate varying degrees of x-parallax over the same geographic area. Figure 5-1 a. gives a good stereo view of only the front driveway of the building.

Figure 37: X-Parallax



Example 1 *Example 2*

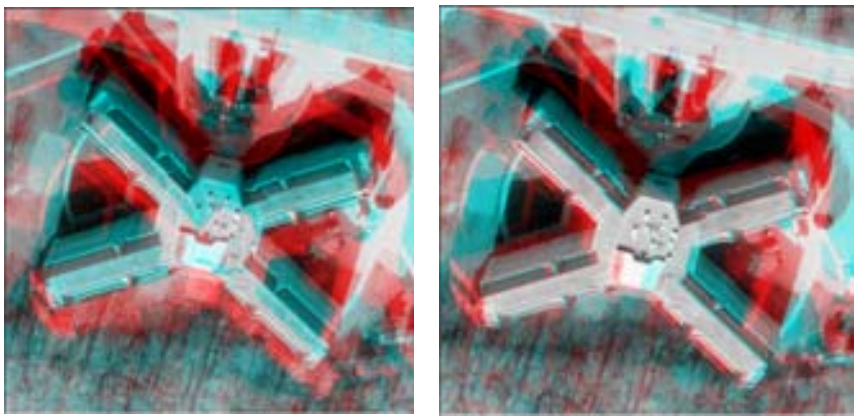
As illustrated in Example 2, both the road and the building can be clearly interpreted in 3D. The optimum amount of x-parallax should provide a clear 3D stereo view throughout the area of interest. Once the ideal x-parallax has been set, you should not need to continually adjust x-parallax within a localized geographic area of interest.

An exception to the rule is an area where a drastic change in elevation exists, like an area of a downtown environment containing both a flat road and a 60 story building. In this case, you have to adjust the zoom level and the x-parallax to effectively perceive 3D for the tall buildings.

Adjusting Y-Parallax

Y-parallax is a phenomenon that causes discomfort while viewing a DSM. The following illustration contains Y-parallax.

Figure 38: Y-Parallax



Example 1 *Example 2*

Two photographs comprising a DSM have been acquired at different positions and orientations (that is, different angles). The difference in position and orientation can be perceived when the overlapping portions of two images are superimposed. Since the two images were exposed at different orientations and positions, the images will never perfectly align on top of one another.

In Stereo Analyst, you must minimize the amount of y-parallax to obtain an accurate and clear 3D DSM. By adjusting y-parallax, you are accounting for the difference in orientation and position between the two images. Thus, once y-parallax has been properly minimized, the difference between the position and orientation of the two images has been accounted for. Example 2, above, shows minimized y-parallax.

Since nonoriented DSMs are created without the use of accurate sensor model information, y-parallax must be minimized throughout various portions of the image while they are being viewed. Using oriented DSMs, Stereo Analyst uses the accurate sensor model information to automatically minimize y-parallax while viewing a given area of interest. This process is also referred to as epipolar resampling on the fly.

Cursor Height Adjustment

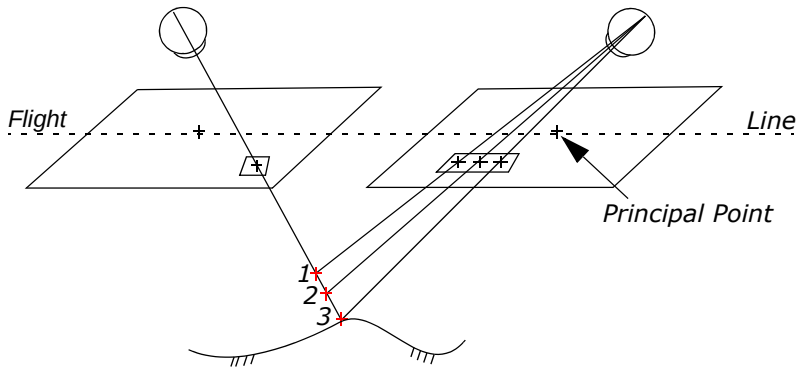
The cursor used in Stereo Analyst can also be referred to as the floating cursor. It is referred to as a floating cursor because the cursor commonly floats above or below the ground while roaming or panning throughout various portions of the DSM. In order to collect accurate 3D geographic information, the cursor must rest on the ground or the human-made feature that is being collected. The floating cursor is the primary measuring mark used in Stereo Analyst to collect and measure 3D geographic information.

The floating cursor consists of a cursor displayed for the left image and a cursor displayed for the right image. The two left and right image cursors define the exact image positions of a feature on the left and right image. Thus, to take a measurement, the location of the cursor on the left image must correspond to the same feature on the right image. Adjusting x-parallax allows you to adjust the left and right image positions so that they correspond to the same feature.

This approach is also used while measuring GCPs to be used for orthorectification. If the image positions of a feature on the left and right image do not correspond, the measurement is inaccurate.

Using Stereo Analyst, the two cursors are adjusted simultaneously so that they fuse into one floating cursor that rests on the ground. To rest the floating cursor on the ground, x-parallax for a given feature must be adjusted. Since the x-parallax contained within a 3D DSM varies with elevation, you need to adjust x-parallax throughout a DSM during 3D point positioning, measurement, and feature collection. A tool known as the automated terrain following cursor automates and simulates the process associated with placing the floating cursor on the ground.

The following illustration shows the effect of adjusting x-parallax for the placement of the floating cursor on the ground.



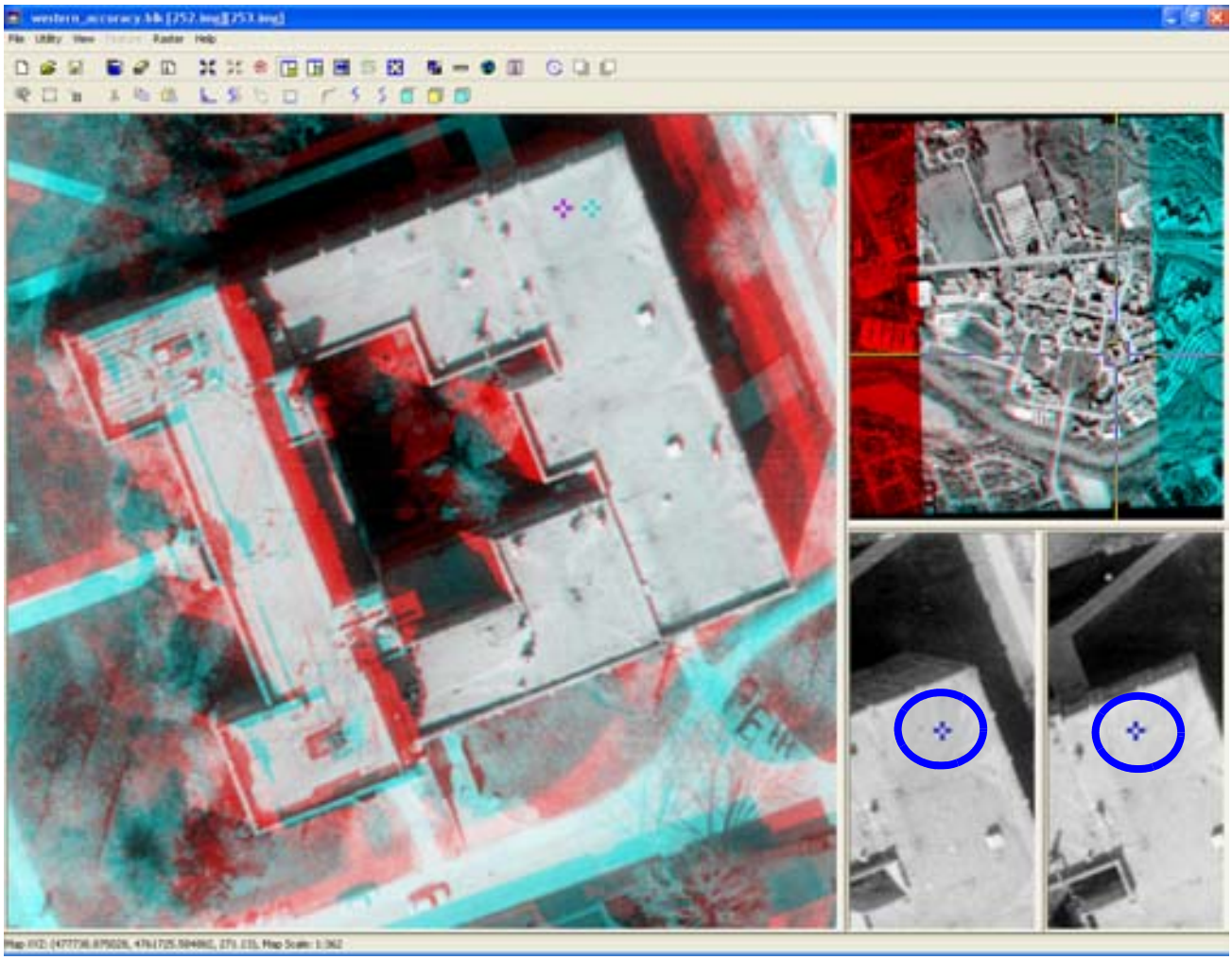
Source: Moffit and Mikhail

Adjusting the floating cursor changes the appearance of the left and right image. The floating cursor is adjusted so that it rests on the feature. Once the floating cursor rests on the feature, the left and right image positions are located on the same feature.

Floating Above a Feature

The following figure illustrates the floating cursor above a feature. Notice that, in the Left and Right Views, the cursor position on the left and right images is located over different features.

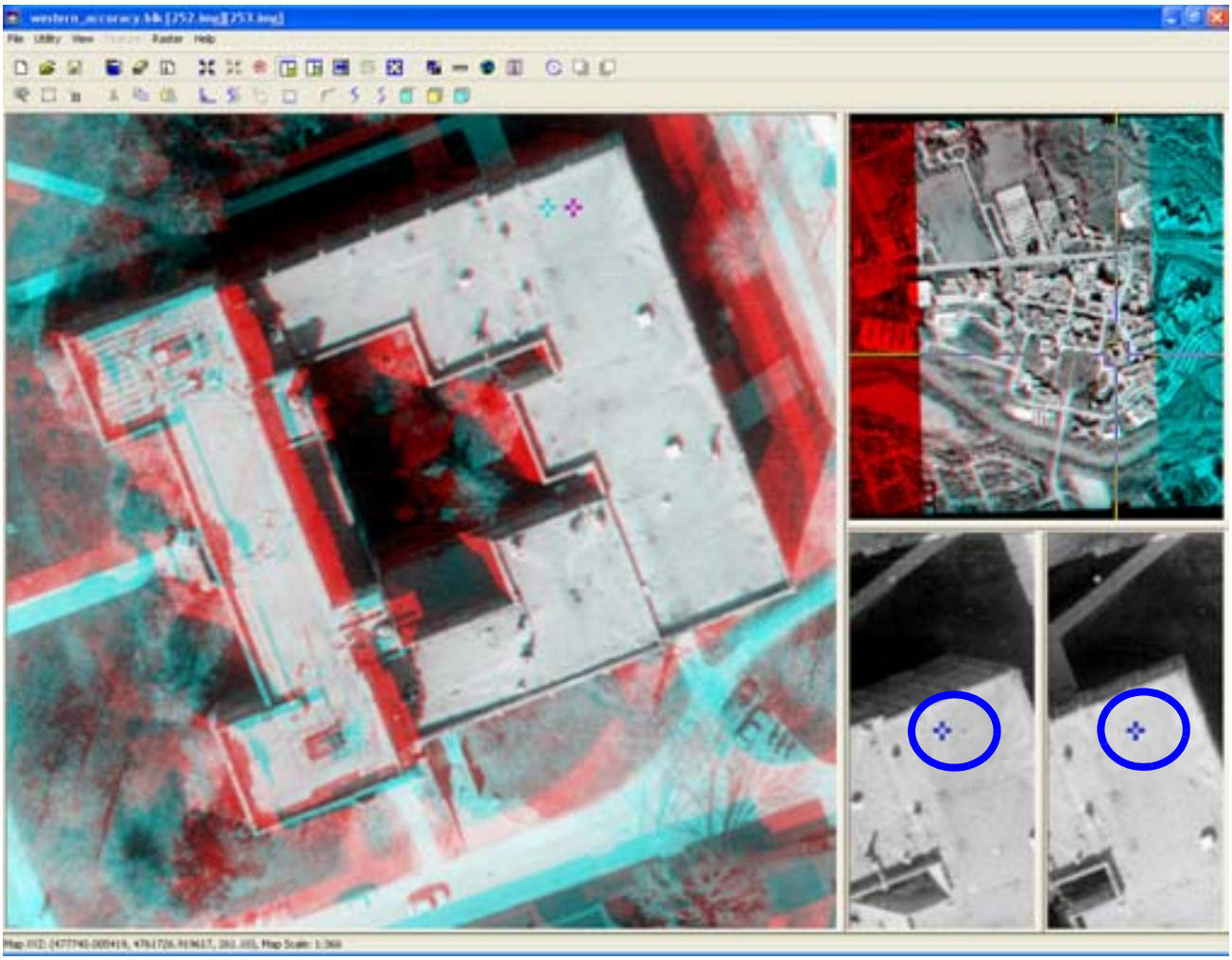
Figure 39: Cursor Floating Above a Feature



Floating Cursor Below a Feature

The following figure illustrates the floating cursor below a feature. Once again, notice that the cursor position on the left and right image is located over different features.

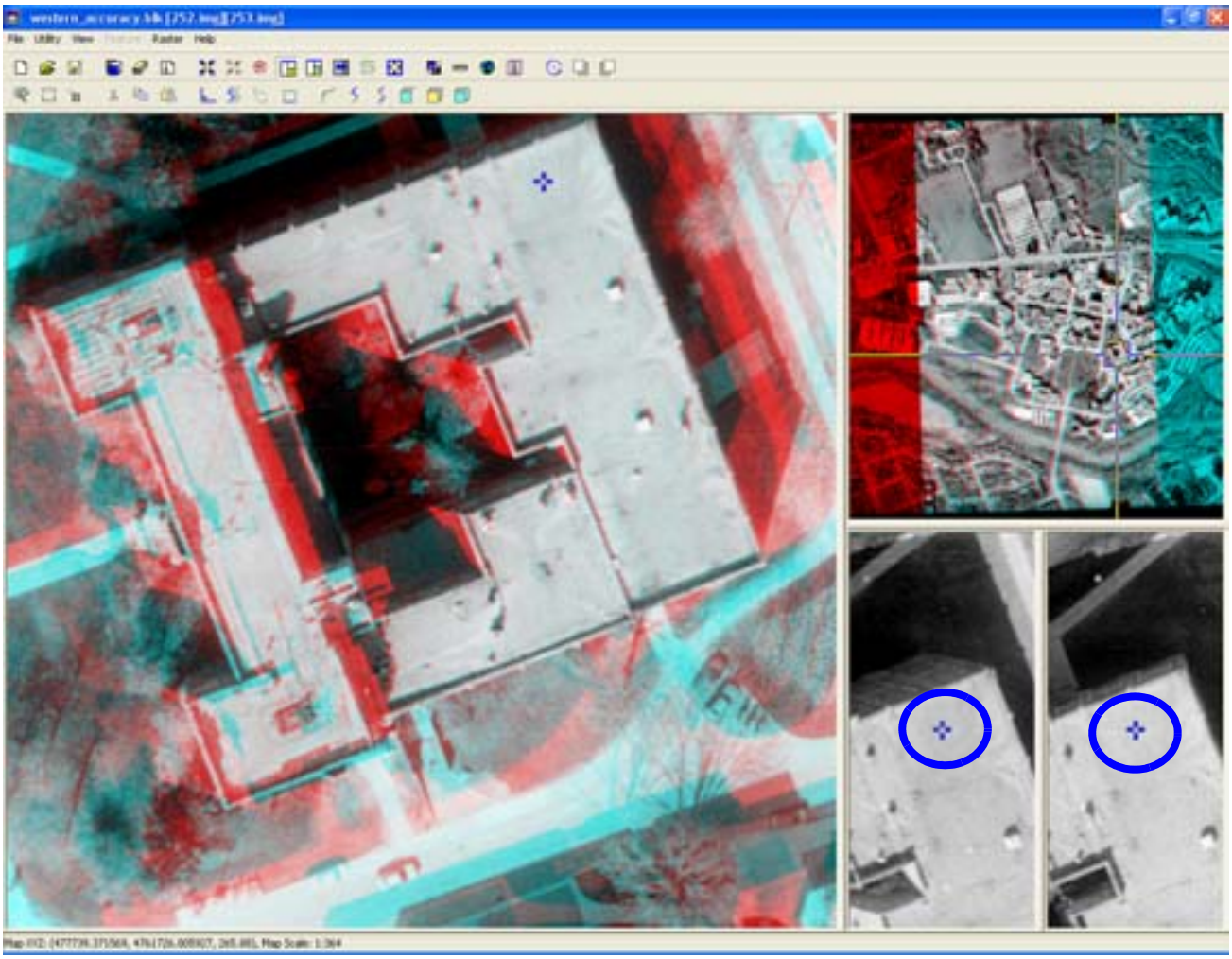
Figure 40: Cursor Floating Below a Feature



Cursor Resting On a Feature

The following figure illustrates the floating cursor resting on the feature of interest. The left and right cursor positions are located on the same feature.

Figure 41: Cursor Resting On a Feature



Next

In the next tour guide, you can learn how to create a DSM using external sources. To do so, you enter calibration, interior, and exterior information, which Stereo Analyst uses to create an block file. A DSM made using this technique is considered oriented, that is, it contains projection information.

Creating a DSM from External Sources

Introduction

This tour guide leads you through the process of creating a DSM using accurate sensor information. The resulting output is an oriented DSM. A DSM can be created and automatically oriented for immediate use in Stereo Analyst. With it, accurate real-world 3D geographic information can be collected from imagery.

Using accurate sensor model information eliminates the process of manually orienting and adjusting the images to create a DSM as you did in the previous tour guide, "Creating a Nonoriented DSM". Stereo Analyst uses sensor information to automatically rotate, level, and scale the two overlapping images to provide a clear DSM for comfortable stereo viewing. Additionally, Stereo Analyst can automatically place the 3D cursor on the terrain, thereby eliminating the need for you to constantly adjust the height of the floating cursor.

The necessary information required to create a DSM can be obtained from the following sources:

- output from 3rd party photogrammetric systems
- output from various data providers
- output from IMAGINE Ortho*MAX*™ and other softcopy photogrammetric software packages

To create a DSM in Stereo Analyst, the following information is required:

- Projection, spheroid, and datum
- Average flying height above ground level used to acquire the imagery
- Rotation order—three rotation angles (that is, Omega, Phi, and Kappa) define the orientation of each image as it existed when it was captured. The orientation is determined relative to an X, Y, and Z coordinate system. The rotation order defines which angle is modeled first, second, and third with respect to the X, Y, and Z coordinate axis. In North America, the order of Omega, Phi, and Kappa is most commonly used.
- Photo direction—the photo direction defines whether the images are aerial or ground-based (that is, terrestrial images). If aerial images are used, the photo direction is the Z-axis. If ground-based images are used, the photo direction is the Y-axis.

- Two overlapping images—these images represent the same geographic area on the surface of the Earth or object being modeled.

- Camera calibration—this is information such as focal length and principal point offset in the x and y direction. This information is commonly provided in a calibration report.

- The six interior orientation coefficients for each image—these six coefficients are also referred to as affine transformation coefficients. They represent the relationship between the file and/or pixel coordinate systems of the image and the film or image space coordinate system. The values summarize the scale and rotation differences between the two coordinate systems.

- The six exterior orientation parameters for each image—the six exterior orientation parameters define the position (X, Y, Z) and orientation (Omega, Phi, Kappa) of each image as they existed when the image was captured. Ensure that the linear and angular units are known.

For detailed information, see "Interior Orientation" and "Exterior Orientation".

Once all of the necessary information has been entered, the resulting output is a block file, which can also be used in LPS Project Manager. The block file format and structure used in Stereo Analyst are identical to the file format and structure used in LPS Project Manager and LPS Automatic Terrain Extraction (ATE).

What is a Block File?

A block file is a file containing two or more images that form a DSM. In most block files, there are more than two images; therefore, you can choose from a number of different image combinations to view in stereo.

Moreover, a block file contains information such as sensor or camera type, projection, horizontal and vertical units, angle units, rotation system, photo direction, and interior and exterior orientation information. When this information is provided to Stereo Analyst, the need for parallax adjustment in the Digital Stereoscope Workspace is eliminated. Stereo Analyst utilizes the accurate sensor model information to automatically adjust parallax to provide a clear DSM.

Stereo Analyst provides the capability to create one oriented DSM at a time. LPS Project Manager, on the other hand, can be used to simultaneously create hundreds of DSMs in one step. Additionally, the block files can be immediately opened in Stereo Analyst and be used to select the DSM of choice.

Specifically, the steps you are going to execute in this example include:

- Select and display the left and right images.
- Open the Create Stereo Model dialog.
- Enter projection information.
- Enter sensor model parameters.
- Save the block file.
- View the block file.

The data you are going to use in this example is of Los Angeles, California. The data is continuous 3-band data with an approximate ground resolution of 0.55 meters. The scale of photography is 1:24,000.

NOTE: The data and imagery used in this tour guide are courtesy of HJW & Associates, Inc., Oakland, California.

Approximate completion time for this tour guide is 45 minutes.

You must have both Stereo Analyst and the example files installed to complete this tour guide.

Getting Started

NOTE: This tour guide was created in color anaglyph mode. If you want your results to match those in this tour guide, set your stereo mode to color anaglyph by selecting **Utility -> Stereo Analyst Options -> Stereo Mode -> Stereo Mode -> Color Anaglyph Stereo***.*

First, you must launch Stereo Analyst. For instructions on launching Stereo Analyst, see "Getting Started".

Once Stereo Analyst has been started and you have an empty Digital Stereoscope Workspace, you are ready to begin.

Load the LA Data

If you have already loaded the LA data set, proceed to the next section "Open the Left Image".

The data you are going to use for this tour guide is not located in the examples directory. Rather, it is included on a data CD that comes with the Stereo Analyst installation packet. To load this data, follow the instructions below.

1. Insert the Stereo Analyst data CD into the CD-ROM drive.
2. Open Windows Explorer.
3. Select the files **la_left.img** and **la_right.img** and copy them to a directory on your local drive where you have write permission.
4. Ensure that the files are not read-only by right clicking to select **Properties**, then making sure that the **Read-only Attribute** is not checked.

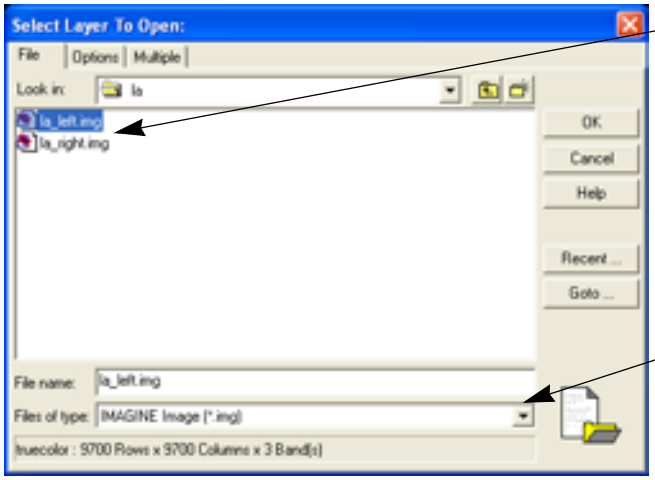
   You are now ready to start the exercise.

Open the Left Image

As in the previous tour guide, you must first open two mono images with which to create the DSM.

1. Click the Open icon on the toolbar of the empty Digital Stereoscope Workspace.

   The Select Layer To Open dialog opens. Here, you select the type of file you want to open in the Digital Stereoscope Workspace.



Select the file la_left.img, the left image of the DSM

This is the first image you use to create the IMAGINE LPS Project Manager block file

Select IMAGINE Image from the dropdown list

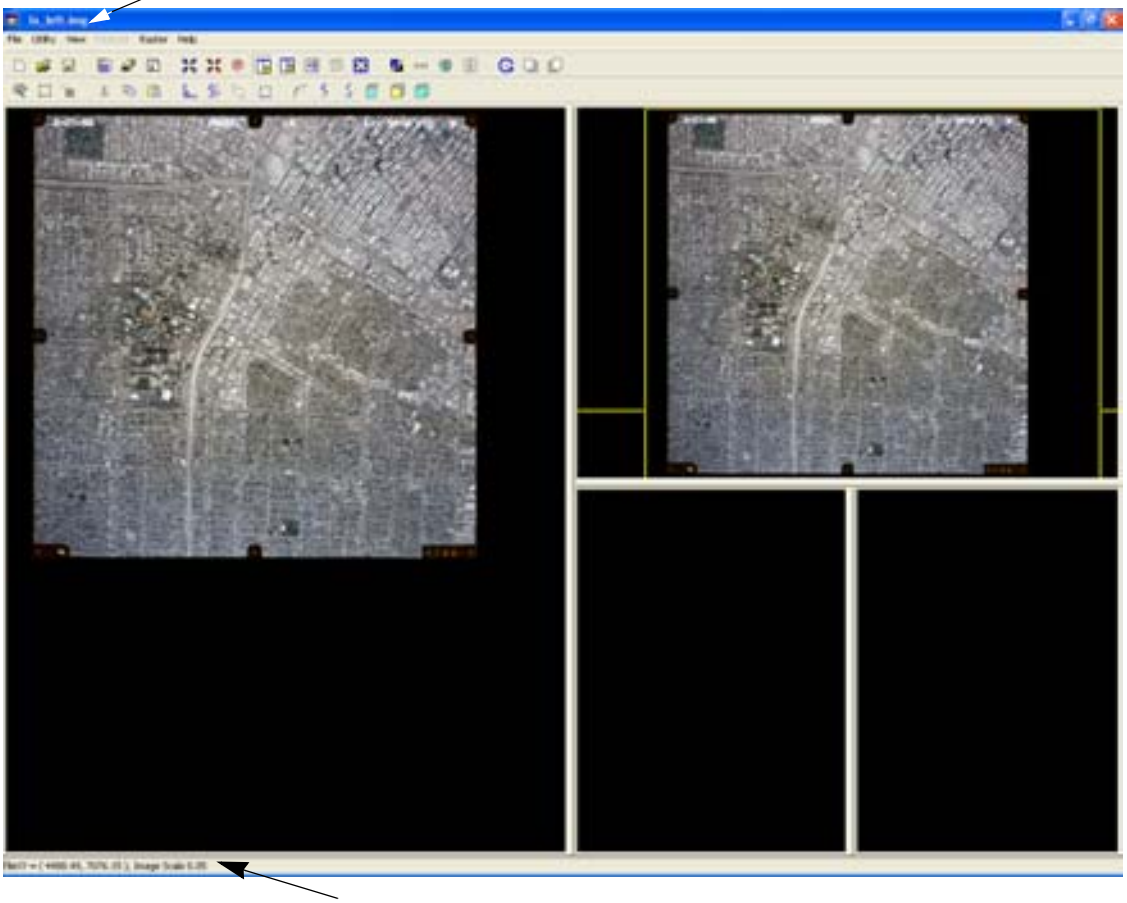
2. Click the **Files of type** dropdown list and select **IMAGINE Image**.
3. Navigate to the directory in which you saved the LA data, then select the file named **la_left.img**.
4. Click **OK** in the Select Layer To Open dialog.

   NOTE: If you have not computed pyramid layers for the image yet, you are prompted to do so.

   The file of Los Angeles, California, **la_left.img**, displays in the Digital Stereoscope Workspace.

   NOTE: The screen captures provided in this tour guide were generated in the Color Anaglyph Stereo mode. If you are running Stereo Analyst with the Quad Buffered Stereo configuration, your images display in true color.

The name of the image displays in the title bar of the Workspace



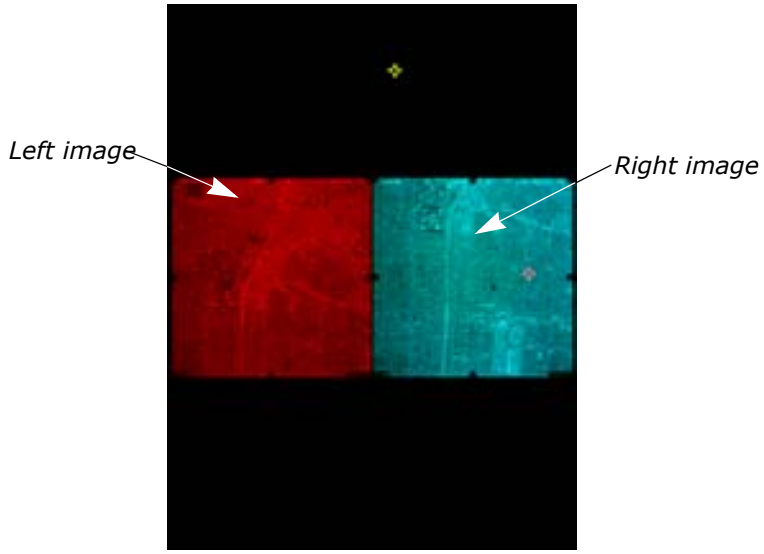
If the image does not have projection information, row and column information displays here

Add a Second Image

Now, you can add a second image so that you can view in stereo.

1. From the **File** menu of the Digital Stereoscope Workspace, select **Open -> Add a Second Image for Stereo**.
2. In the Select Layer To Open dialog, navigate to the directory where you saved the LA data and select the image **la_right.img**.
3. Click **OK** in the Select Layer To Open dialog.

   The images display in the Digital Stereoscope Workspace.



Now that you have both of the images from which to create an oriented DSM displayed in the Digital Stereoscope Workspace, you can open the Create Stereo Model dialog.

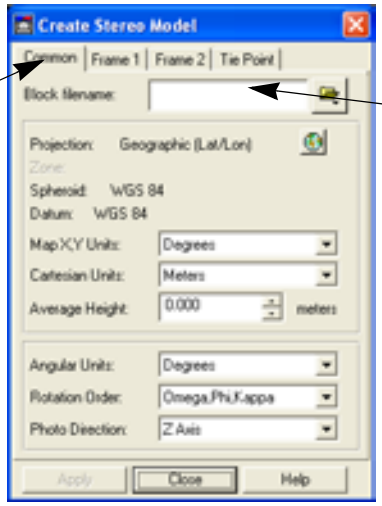
Open the Create Stereo Model Dialog

Stereo Analyst provides the Create Stereo Model dialog to enable you to create oriented DSMs from individual images that have associated sensor model information. The resulting DSM is stored as a block file.

1. From the toolbar of the Digital Stereoscope Workspace, click the Create Stereo Model icon .

You can also open the Create Stereo Model dialog by selecting **Utility -> Create Stereo Model Tool**.

The Create Stereo Model dialog opens on the **Common** tab.



The Create Stereo Model dialog opens on the Common tab

You enter the name of the new LPS Project Manager block file here

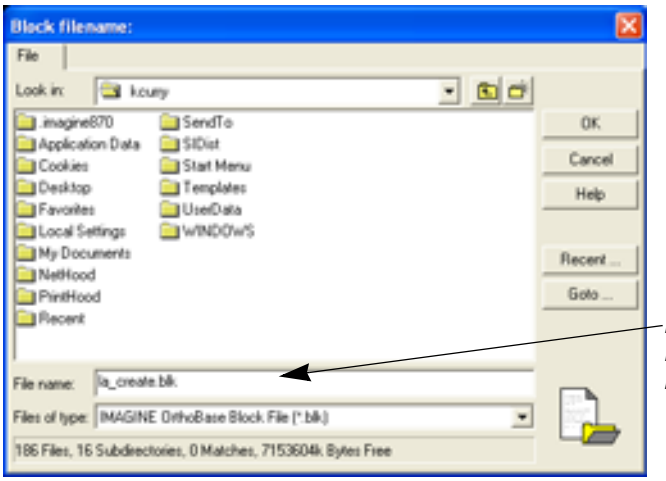
You can navigate to a specific directory via the Block filename icon

Name the Block File

1. In the Create Stereo Model dialog, click the Block filename icon .

   NOTE: If you are running Stereo Analyst in conjunction with ERDAS IMAGINE, the default output directory is determined by the **Default Output Directory** *you have set in the* **User Interface & Session** *category of your ERDAS IMAGINE Preferences.*

   The Block filename dialog opens.



Name the IMAGINE LPS Project Manager block file here

2. Navigate to a directory in which you have write permission.

3. Click in the **File name** field and type the name **la_create**, then press Enter on your keyboard. The .blk extension (block file) is automatically appended.

4. Click **OK** in the Block filename dialog to accept the name for the block file.

   The Create Stereo Model dialog is updated with the information.

Enter Projection Information

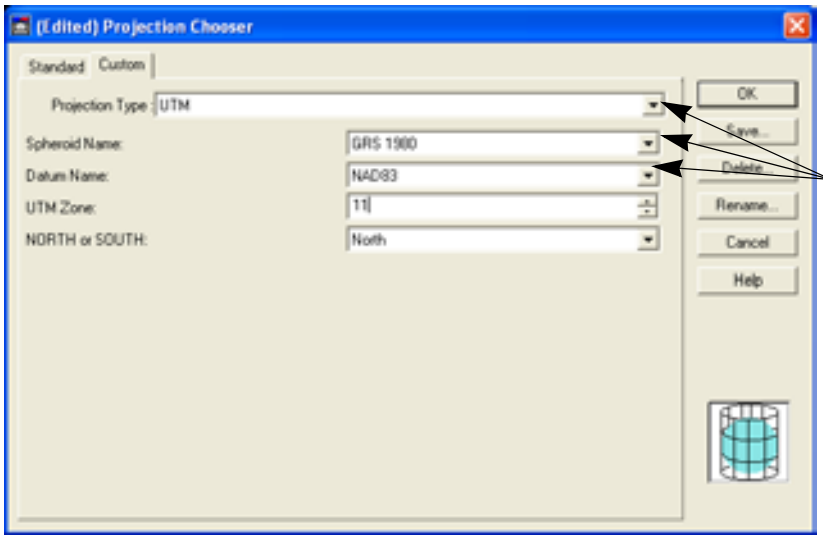
To change the projection information, you access another series of dialogs.

1. In the Create Stereo Model dialog, click the Projection icon .

   The Projection Chooser dialog opens.

2. In the **Custom** tab of the Projection Chooser dialog, click the **Projection Type** dropdown list and choose **UTM**.
3. Click the **Spheroid Name** dropdown list and choose **GRS 1980**.
4. Click the **Datum Name** dropdown list and choose **NAD83**.
5. Use the arrows, or type the value **11** in the **UTM Zone** field.
6. Confirm that the **NORTH or SOUTH** window displays **North**.

   When you are finished, the Projection Chooser looks like the following.



For more information about projections, see the ERDAS IMAGINE On-Line Help.

7. Click **OK** in the Projection Chooser dialog to transfer the information to the Create Stereo Model dialog.
8. Confirm that the **Map X,Y Units** are set to **Meters**.
9. Confirm that the **Cartesian Units** are set to **Meters**.

10. Enter the value **3925** in the **Average Height** in **meters** field, then press Enter on your keyboard.

    The average height is also referred to as the average flying height. The average height is the average elevation of the aircraft above the ground as it captured the images used to create the DSM.

11. Confirm that the **Angular Units** are set to **Degrees**.

    Angular units are the units used to define the orientation angles: Omega (ω), Phi (φ), and Kappa (κ).

12. Confirm that the **Rotation Order** is set to **Omega, Phi, Kappa**.

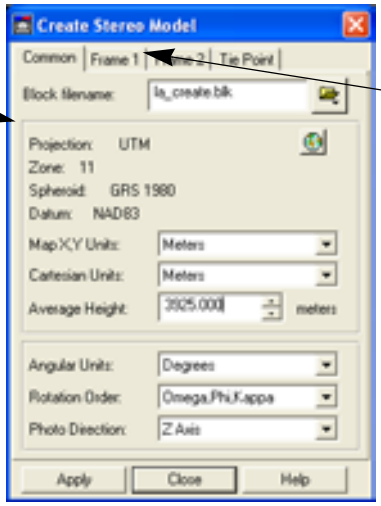
    The angular or rotational elements associated with a sensor model (Omega, Phi, and Kappa) describe the relationship between the ground coordinate system (X, Y, Z) and the image coordinate system. Different conventions are used to define the order and direction of the three rotation angles.

    ISPRS recommends the use of the Omega, Phi, and Kappa convention or order. In this case, Omega is a positive rotation around the X-axis, Phi is a positive rotation about the Y-axis, and Kappa is a positive rotation around the Z-axis. In this system, X is the primary axis.

13. Confirm that the **Photo Direction** is set to **Z Axis**.

    The Z-axis is selected when you use aerial photography or imagery. Aerial photographs have the optical axis of the camera directed toward the Z-axis of the ground coordinate system. If ground-based or terrestrial imagery is being used, the Y-axis should be selected as the photo direction.

    When you have finished, the **Common** tab of the Create Stereo Model dialog looks like the following.



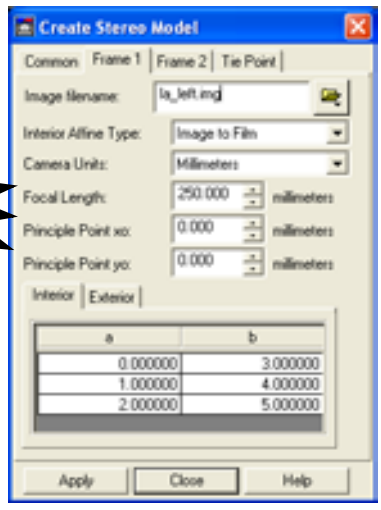
Projection information displays here

Once the common elements are specified, you can enter information about the first image in the Frame 1 tab

Enter Frame 1 Information

Next, you must define the parameters of the camera that collected the first image you intend to use in the block file. To incorporate this information, you must do so in the **Frame 1** tab of the Create Stereo Model dialog.

1. Click the **Frame 1** tab located at the top of the Create Stereo Model dialog.



This information is also in the Frame 2 tab

Notice that the **Image filename** section of the **Frame 1** tab is already populated with a file, **la_left.img**. This field is automatically populated with the first image you choose when you initially open the Digital Stereoscope Workspace.

2. Confirm that the **Interior Affine Type** is set to **Image to Film**.

The interior affine type defines the convention used to display the six coefficients that describe the relationship between the image and film coordinate systems. The image coordinate system is defined in pixels, while the film (that is, photo) coordinate system can be defined in millimeters, microns, etc.

The options include **Image to Film** and **Film to Image**. The **Image to Film** option describes the six affine transform coefficients going from pixels to linear units such as millimeters or microns. The **Film to Image** option describes the six affine transform coefficients going from linear units to pixels. The option you select defines how the six values are entered into the Create Stereo Model dialog.

3. Confirm that the **Camera Units** are set to **Millimeters**.

   The camera units should correspond to the camera calibration values used for focal length and principal point in the x and y direction.

4. In the **Focal Length** field, type a value of **154.047**, then press Enter on your keyboard.

   The focal length of the camera is provided with the calibration report.

5. In the **Principle Point xo** field, type a value of **0.002**, then press Enter.

   The principal point offset in the x direction is commonly provided with the calibration report that comes with the imagery.

6. In the **Principle Point yo** field, type a value of **-0.004**, then press Enter.

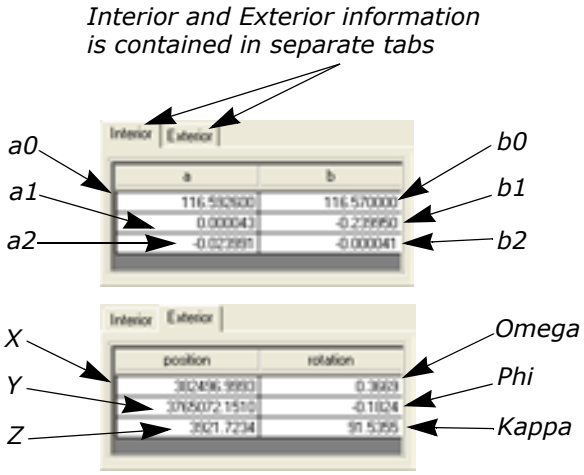
   The principal point offset in the y direction is commonly provided with the calibration report that comes with the imagery.

For additional information about these parameters see "Digital Mapping Solutions".

Add Interior and Exterior Information for Frame 1, la_left.img

At the bottom of the **Frame 1** tab of the Create Stereo Model dialog, there are two additional tabs that allow you to provide sensor model information associated with the imagery as it existed when the data was captured. These two tabs, **Interior** and **Exterior**, can be updated with information provided by the data vendor.

The **Interior** tab allows for the input of the six interior orientation affine transformation coefficients (that is, a0, a1, a2, b0, b1, b2). The **Exterior** tab allows for the input of the six exterior orientation parameters of the image (that is, X, Y, Z, Omega, Phi, Kappa).



Do not enter commas into the **Interior** *orientation CellArray™.*

1. Using the following table, type the six coefficient values for **la_left.img** into the **Interior** tab.

Table 5: Interior Orientation Parameters for Frame 1, la_left.img

	a		b
a0:	116.5926	b0:	116.5700
a1:	0.000043	b1:	-0.023995
a2:	-0.023991	b2:	-0.000041

2. Click the **Exterior** tab.

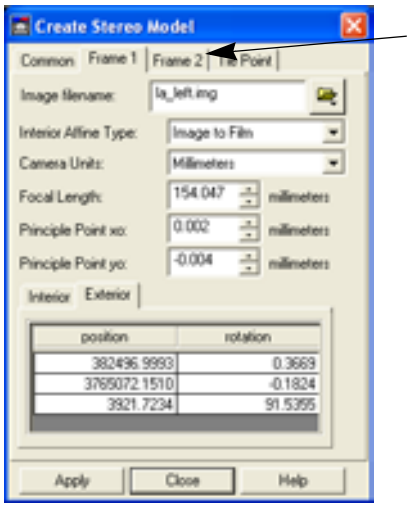
Do not enter commas in the **Exterior** *orientation CellArray.*

3. Using the following table, type the six exterior orientation parameters into the **Exterior** tab.

Table 6: Exterior Orientation Parameters for Frame 1, la_left.img

	position		rotation
X:	382496.9993	Omega:	0.3669
Y:	3765072.1510	Phi:	-0.1824
Z:	3921.7234	Kappa:	91.5355

When you have finished, the **Frame 1** tab of the Create Stereo Model dialog looks like the following.



Next, you enter information for the second image in the Frame 2 tab

Add Interior and Exterior Information for Frame 2, la_right.img

Do not enter commas in the **Interior** *and* **Exterior** *orientation CellArrays.*

1. Click the **Frame 2** tab at the top of the Create Stereo Model dialog.

   Information from the **Frame 1** tab, **Focal Length** and **Principal Point xo** and **yo**, transfers to the **Frame 2** tab automatically.

2. Using the following table, type the six coefficients into the **Interior** tab.

Table 7: Interior Orientation Parameters for Frame 2, la_right.img

	a		b
a0:	116.2486	b0:	116.8011
a1:	0.000018	b1:	-0.023992
a2:	-0.023987	b2:	-0.000017

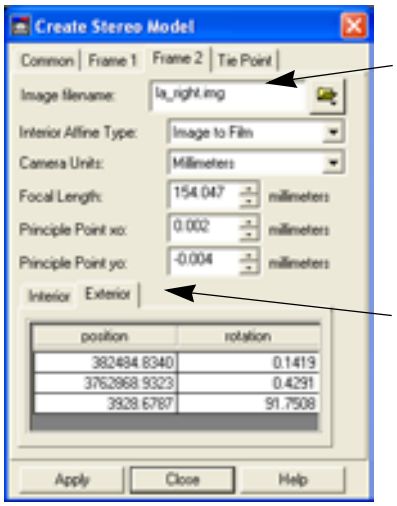
3. Click the **Exterior** tab.

4. Using the following table, type the six exterior orientation parameters into the **Exterior** tab.

Table 8: Exterior Orientation Parameters for Frame 2, la_right.img

	position		rotation
X:	382484.8340	Omega:	0.1419
Y:	3762868.9323	Phi:	0.4291
Z:	3928.6787	Kappa:	91.7508

When you have finished, the **Frame 2** tab of the Create Stereo Model dialog looks like the following.



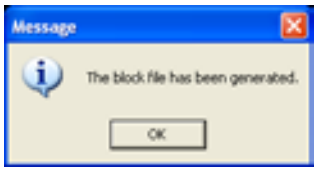
The name of the second image displays here

Exterior and Interior information specific to the second image is input here

Apply the Information

1. In the Create Stereo Model dialog, click the **Apply** button.

   Once the **Apply** button has been selected, all of the image sensor model information is saved to the block file.



2. Click the **Close** button to dismiss the Create Stereo Model dialog.
3. In the Digital Stereoscope Workspace, click the Clear Viewer icon .

Open the Block File

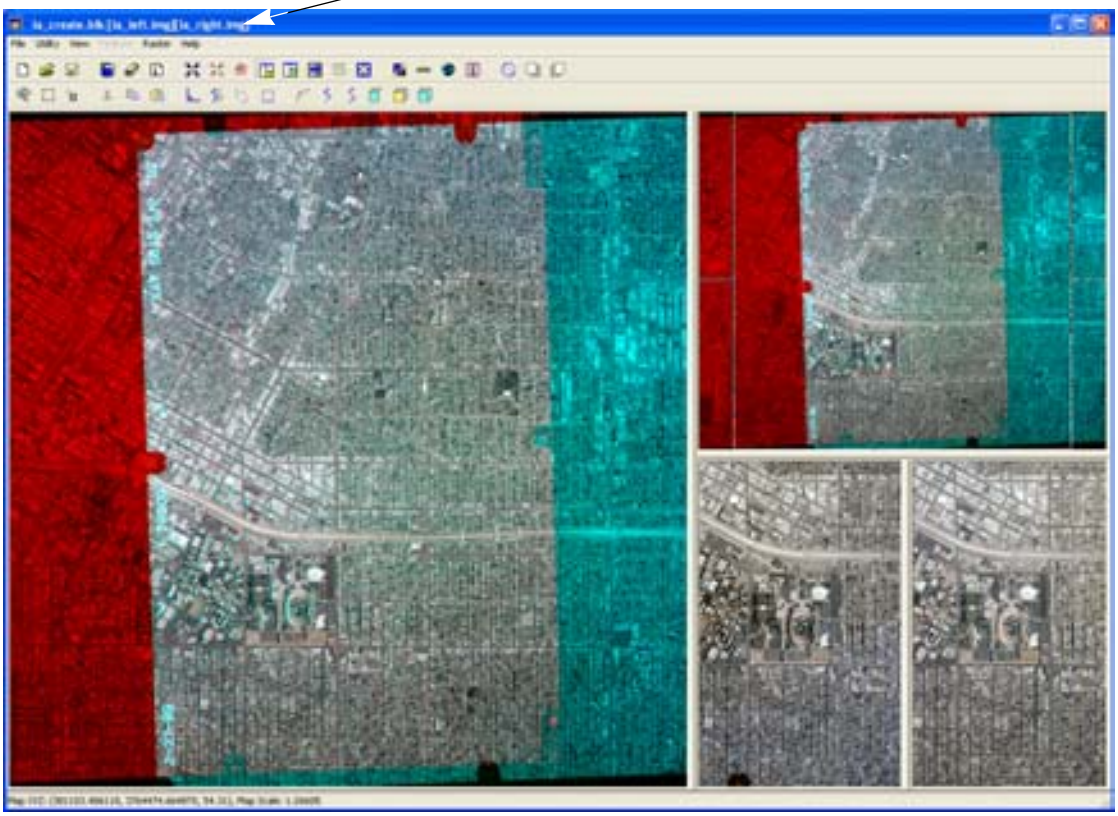
To view the DSM, you need to open the block file that contains the sensor model information.

For the remainder of the tour guide, you need either red/blue glasses or stereo glasses that work in conjunction with an emitter.

1. Click the Open icon in the Digital Stereoscope Workspace.
2. In the Select Layer To Open dialog, click the **Files of type** dropdown list and select **IMAGINE OrthoBASE Block File (*.blk)**.
3. Navigate to the directory in which you saved **la_create.blk**.
4. Click to select the file, then click **OK** in the Select Layer To Open dialog.

   The block file you created, **la_create.blk**, displays in the Digital Stereoscope Workspace.

The block file DSM is composed of la_left.img and la_right.img, as shown here



5. Adjust the x-parallax as necessary to improve the appearance of the DSM.

The two images comprising the DSM have been superimposed. Using the sensor model information, the difference between the left and right image orientation and position has been considered. Thus, the images do not need to be rotated, scaled, leveled, or adjusted for y-parallax. Stereo Analyst has automatically performed this task.

Prior to viewing the DSM in 3D, the images must be adjusted so as to minimize the x-parallax in the model. An alternative approach to improving the alignment and eliminating the need to adjust the x-parallax to obtain a clear DSM includes entering a tie point position while creating a block file. The left and right image position of a tie point can be input in the **Tie Point** tab of the Create Stereo Model dialog. The left and right image position for the tie point must reflect the same feature on the surface of the Earth. The values must be in pixels.

NOTE: Leica Geosystems is currently researching various approaches for eliminating the need to enter a tie point value.

6. Click the Clear Viewer icon .

7. Select **File -> Exit Workspace** to close Stereo Analyst if you wish.

Next

In the next tour guide, the Position tool is used to verify the quality and accuracy associated with an oriented DSM.

3D check points having X, Y, and Z coordinates are used to independently check the accuracy of a DSM. The 3D Position tool can also be used to determine the 2D and 3D accuracy of a GIS layer that is stored as an ESRI Shapefile.

Checking the Accuracy of a DSM

Introduction

This tour guide describes the techniques used to determine the accuracy of a DSM. Using 3D X, Y, Z check points, the accuracy of an oriented DSM can be determined. Similarly, using 3D check points, the accuracy of GIS layers can also be determined. The Position tool in Stereo Analyst is used to enter 3D check point coordinates, which are then compared to the position displayed in the 3D stereo view. If the check point is correct, the 3D floating cursor should rest on the feature or object of interest. If the check point is incorrect, the following characteristics may be apparent:

- The 3D floating cursor may be offset in the X and/or Y direction.
- The 3D floating cursor may be positioned above the feature or object.
- The 3D floating cursor may be positioned below the feature or object.

If a check point is incorrect, the difference in the X, Y, and Z direction between the original position and the displayed position can be visually interpreted and recorded.

The Position tool can also be used to collect 3D point positions for use in other applications. The resulting 3D point positions can be used for geocorrection, orthorectification, or highly accurate point determination.

Specifically, the steps you are going to execute in this example include:

- Select a block file.
- Open the Stereo Pair Chooser.
- Select a DSM.
- Open the Position tool.
- Enter the 3D coordinates of the check points into the Position tool.
- Observe the check point positions in 3D stereo.
- Record the difference between the original 3D check point position and the displayed check point position.

The data used in this tour guide covers the campus of The University of Western Ontario in London, Ontario, Canada. The four photographs were captured at a photographic scale of 1:6000. The photographs were scanned at a resolution of 25 microns. The resulting ground coverage is 0.15 meters per pixel.

Seven check points are used to check the accuracy of the DSM. The seven check points were calculated using conventional surveying techniques to an accuracy of approximately 0.05 meters in the X, Y, and Z directions.

Approximate completion time for this tour guide is 30 minutes.

You must have both Stereo Analyst and the example files installed to complete this tour guide.

Getting Started

NOTE: This tour guide was created in color anaglyph mode. If you want your results to match those in this tour guide, set your stereo mode to color anaglyph by selecting **Utility -> Stereo Analyst Options -> Stereo Mode -> Stereo Mode -> Color Anaglyph Stereo**.

First, you must launch Stereo Analyst. For instructions on launching Stereo Analyst, see "Getting Started".

Once Stereo Analyst has been started and you have an empty Digital Stereoscope Workspace, you are ready to begin.

Open a Block File

The first step in checking the accuracy of the DSM involves opening a block file. The block file contains all of the necessary information required to automatically create and display a DSM in real-time.

The block file in this example was created in LPS Project Manager. Camera calibration and GCP information was input and used to calculate all of the necessary sensor model information. The resulting accurate sensor model information is used to calculate and display 3D coordinate information.

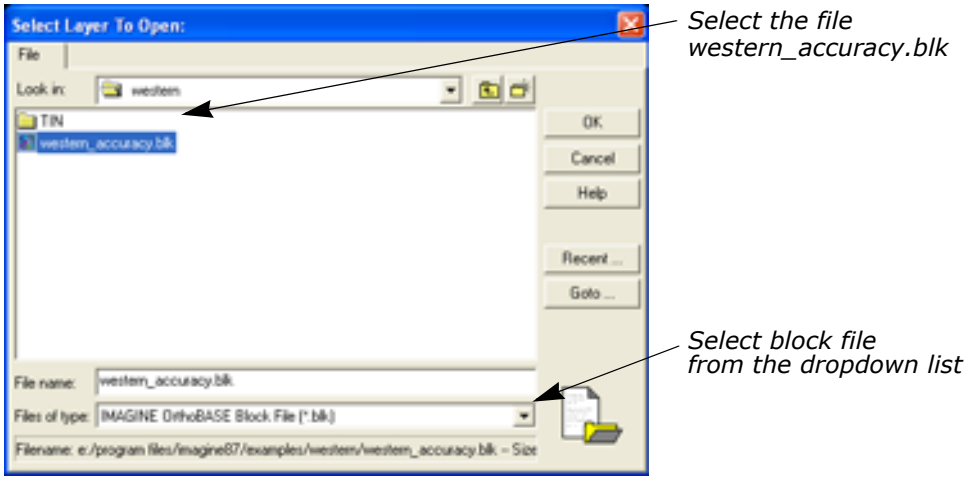
For the remainder of the tour guide, you need either red/blue glasses or stereo glasses that work in conjunction with an emitter.

Select the Workspace and Add the .blk File

1. From the toolbar of the empty Digital Stereoscope Workspace, click the Open icon .

   The Select Layer To Open dialog opens. Here, you select the type of file you want to open in the Digital Stereoscope Workspace.

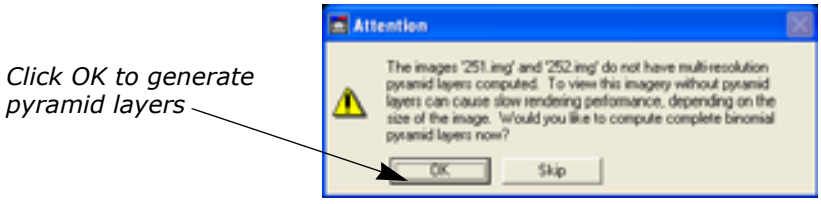
2. Click the **Files of type** dropdown list and select **IMAGINE OrthoBASE Block File**.



3. Navigate to the <IMAGINE_HOME>\examples\Western directory, then select the file named **western_accuracy.blk**.

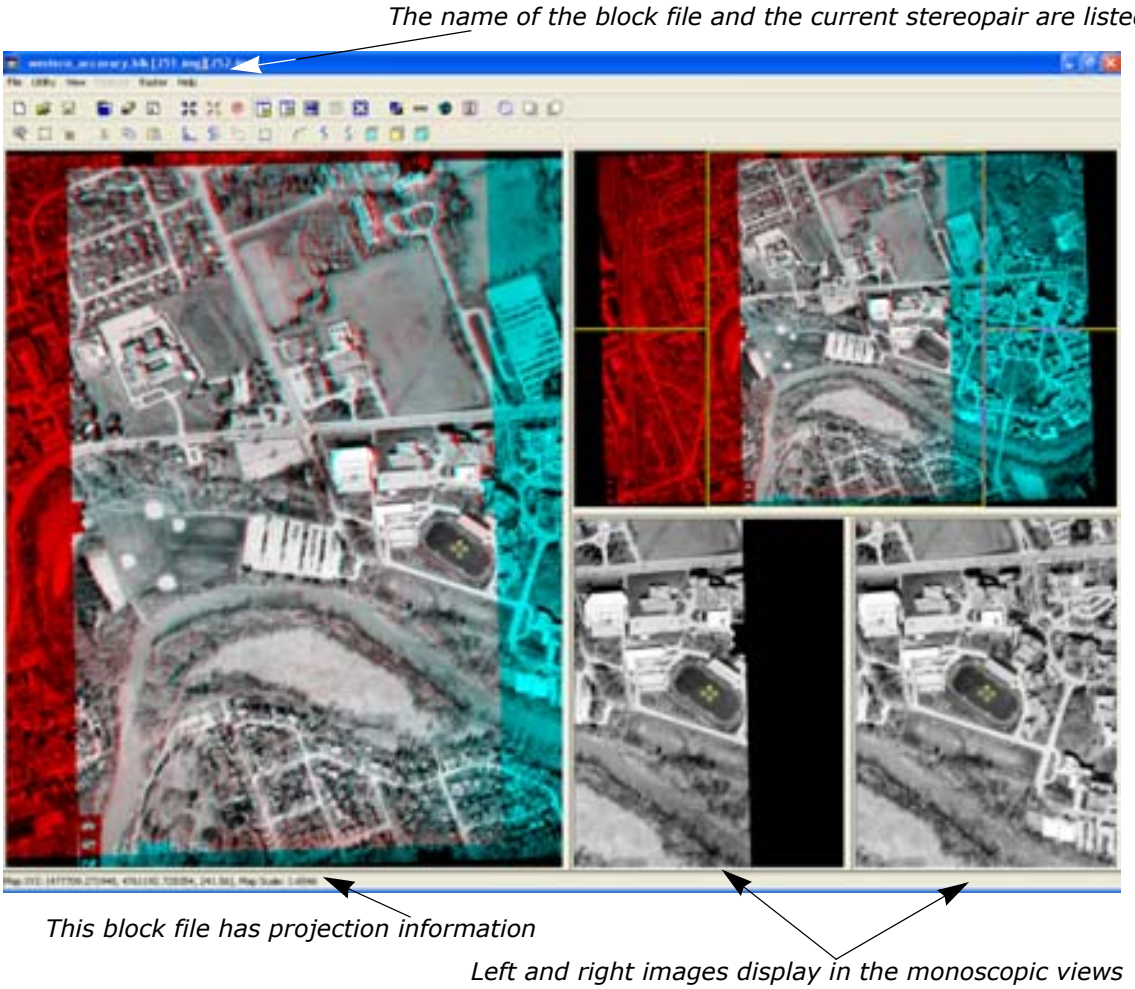
4. Click **OK** in the Select Layer To Open dialog.

   A dialog opens that prompts you to create pyramid layers for the files in the block file **western_accuracy.blk**. Once you create pyramid layers for the files, you are not prompted to do so again.



5. Click **OK** to compute pyramid layers.

   After the pyramid layers are generated, the block file of The University of Western Ontario displays in the Digital Stereoscope Workspace. If the block file contains more than one DSM, Stereo Analyst automatically displays the first DSM in the block file. Options described later in this tour guide can be used to select other DSMs contained within the block file.



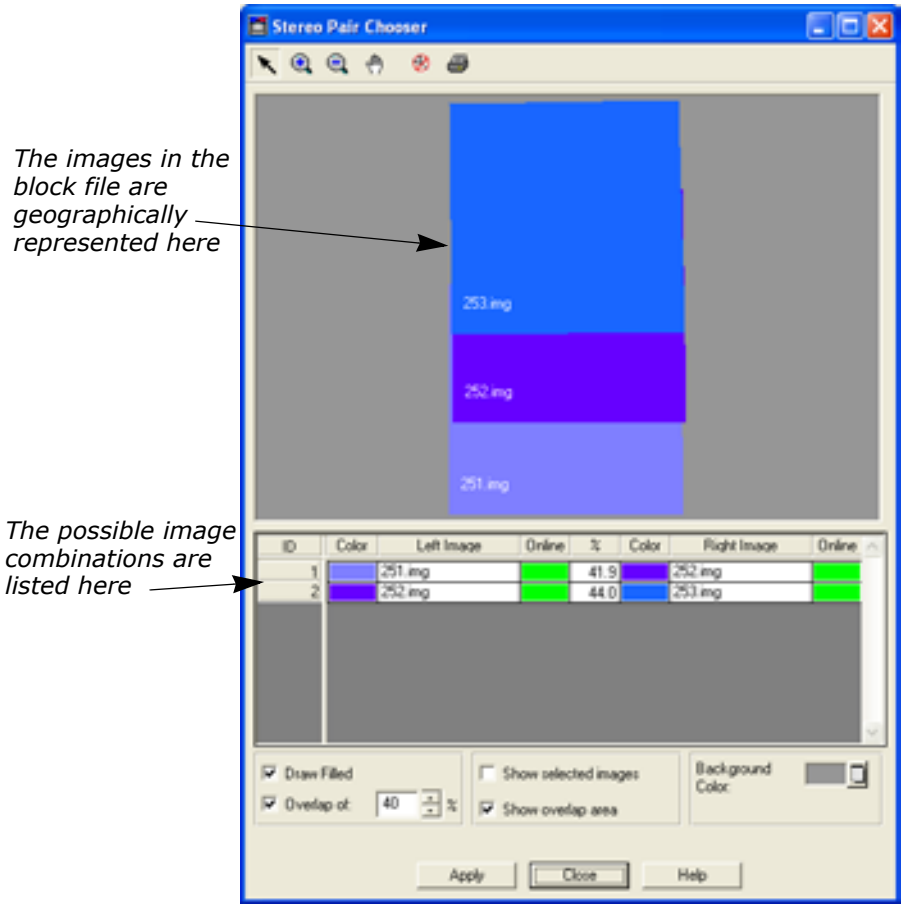
If you wish to view only the overlapping area of the two photographs comprising a DSM, you can set an option to that effect. From the **Utility** *menu, select* **Stereo Analyst Options**. *Then, click the* **Stereo View Options** *option category. Click to select the* **Mask Out Non-Stereo Regions** *option.*

Open the Stereo Pair Chooser

You can select various DSMs from the **western_accuracy.blk** file. To do so, you open the Stereo Pair Chooser dialog. With it, you can select a DSM that suits criteria you specify, such as overlap area.

1. In the Digital Stereoscope Workspace, click the Stereo Pair Chooser icon .

   The Stereo Pair Chooser dialog opens.

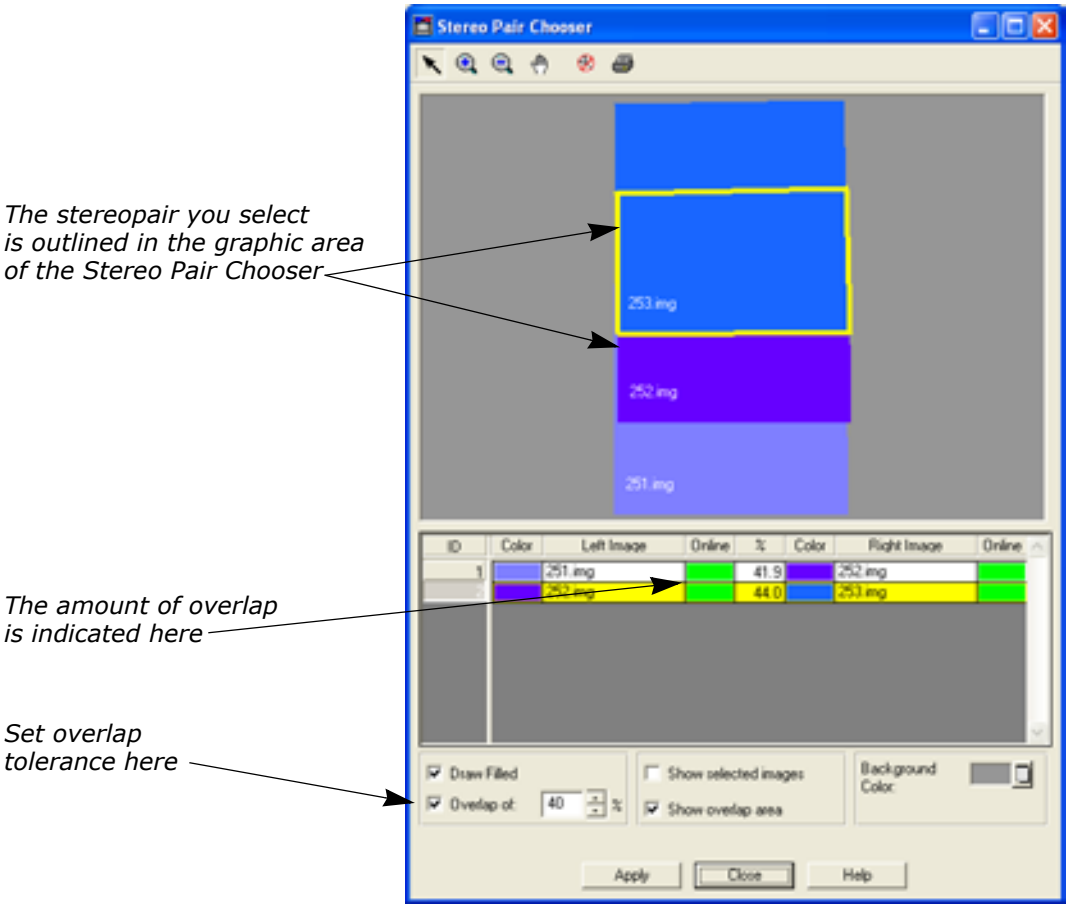


The Stereo Pair Chooser is equipped with a CellArray. You can use the CellArray to select different image pairs from the block file. These image pairs can then be displayed in the stereo view.

The overlap areas of the image footprints displayed in the Stereo Pair Chooser can also be interactively selected to choose a DSM of interest. Once a DSM has been graphically selected, the corresponding images are highlighted in the CellArray.

2. Click to select row **2** in the **ID** column. This is the DSM consisting of images **252.img** and **253.img**.

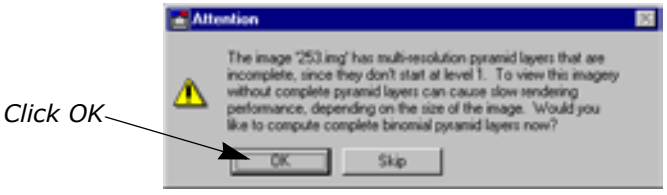
   When you have selected that row, the Stereo Pair Chooser looks like the following.



Notice that the highlighted row corresponds to the appropriate DSM footprint in the Stereo Pair Chooser. You can see the overlap area that is going to be displayed in the Digital Stereoscope Workspace. In this case, the area contains approximately 44% overlap.

3. Click **Apply** in the Stereo Pair Chooser dialog.

   Again, you may be prompted to calculate pyramid layers, this time for the image **253.img**.



4. If necessary, click **OK** in the Attention dialog to compute pyramid layers for **253.img**.

   The DSM updates in the Stereo Analyst Digital Stereoscope Workspace.

5. Click **Close** in the Stereo Pair Chooser dialog.

The selected DSM displays in the Digital Stereoscope Workspace.

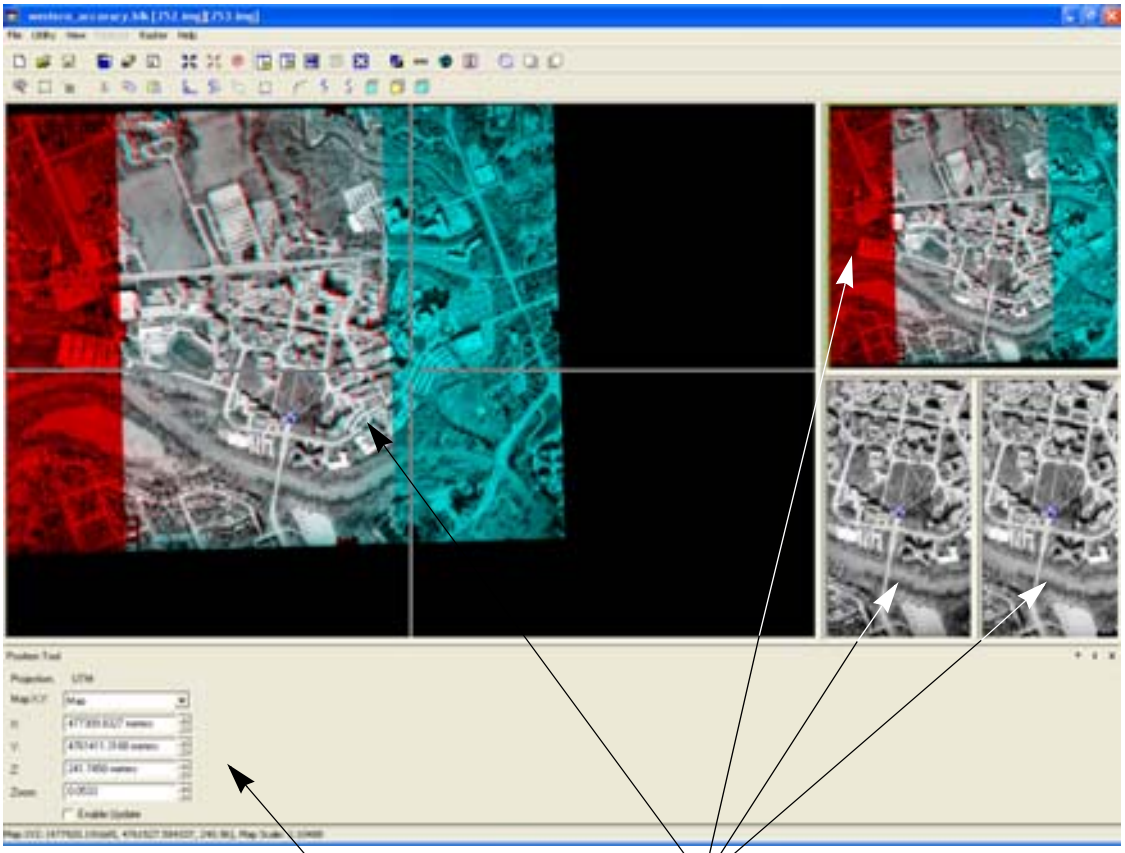
Open the Position Tool

Now that you have the appropriate DSM displayed, you can use some of the other Stereo Analyst tools to check the accuracy of the data. In this portion of the tour guide, you are going to work with the Position tool.

You can use the Position tool to check the accuracy of the DSM and the associated quality of the sensor model information contained in the block file.

1. With the stereopair **252.img** and **253.img** displayed in the Digital Stereoscope Workspace, click the Position tool .

   Once selected, the Position tool becomes embedded in the bottom portion of the Digital Stereoscope Workspace. Thus, all of the tools required for checking accuracy are contained within one environment.



Use the Position Tool

To use the Position tool, you are going to type in X, Y, and Z coordinates of check points. Check points can be used to check the accuracy of the DSM in the block file.

First Check Point

1. Ensure that the **Enable Update** button is not checked in the Position tool.
2. Ensure that the **Map X,Y** option is set to **Map**.

   NOTE: The units of the X, Y, and Z check point positions are determined based on the sensor model information contained in the block file.
3. Type **1.0** in the **Zoom** field.

   NOTE: The zoom is approximately 1.0.

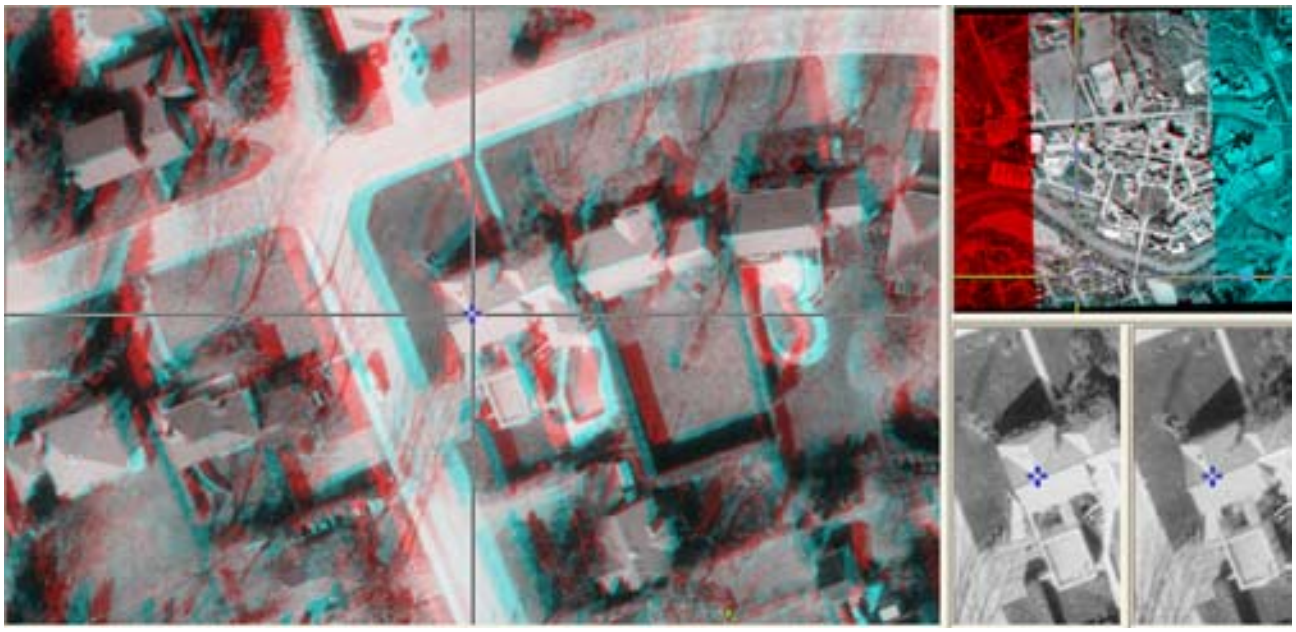
4. In the Position tool, double-click the value in the **X** field and type the value **478221.57**, then press Enter on your keyboard.

5. Double-click the value in the **Y** field and type the value **4761174.72**, then press Enter on your keyboard.

6. Double-click the value in the **Z** field and type the value **247.24**, then press Enter on your keyboard.

   To change the appearance of the crosshair, select **Utility -> Stereo Analyst Options -> Cursor Display -> Cursor Shape**. *There, you can choose a crosshair best suited to your application.*

   Notice that, as you are typing in coordinates, the display is driving to the coordinates you specify. In this example, you are taken to the first check point position: it is located at the intersection of two roof lines.



7. Position the cursor over the intersection of the crosshair to see the specific point in the Left and Right monoscopic Views.

   The cursor on the left and right images comprising the DSM should be centered over the same feature (the intersection of the two roof lines).

8. While viewing in stereo, visually interpret the location of the 3D floating cursor over the feature.

   The X and Y position should be located at the intersection of the two roof lines. The 3D cursor should be resting on the roof.

Compute X and Y Coordinate Accuracy

1. If the X and/or Y position of the floating cursor is incorrect, select the **Enable Update** option in the Position tool.
2. Adjust the coordinates in the Position tool by dragging the image so that the crosshair overlaps the intersection of the two roof lines.
3. Once you have determined the correct X and Y position, select the **Enable Update** option once again to disable that capability.
4. Record the new **X** and **Y** coordinate positions displayed in the Position tool.
5. To determine the offset associated with the original X and Y coordinate values, subtract the old values from the new values.

   The resulting values indicate the accuracy of the DSM in the X and Y direction over a specific point.

Determining Stereo Model Accuracy—X and Y Coordinates

The best way to determine the accuracy of a DSM is to compare your results with coordinates provided to you. The following **Original** coordinates correspond to the first check point. You supply the **New** check point coordinates as you perceive them in the Digital Stereoscope Workspace. The difference between them is the accuracy value. In this example, the accuracy is quite good.

Original Check Point 1 Coordinates	New Check Point 1 Coordinates	Difference
X = 478221.57	X = 478221.3923	-0.18
Y = 4761174.72	Y = 4761174.7167	-0.0033

Compute Z Elevation Accuracy

1. Place the 3D cursor over the feature of interest.

   The 3D floating cursor should be located within the center point of the crosshair. Ensure that the X and Y location of the 3D floating cursor remains at the intersection of the two roof lines.
2. If the 3D cursor is not resting on the roof, adjust the floating cursor by rolling the mouse wheel.

For information on cursor height adjustment, see "Position the 3D Cursor".

As the 3D floating cursor is being adjusted, the elevation value associated with the Z coordinate is adjusted in the status area.

3. Once the floating cursor is adjusted, record the new **Z** coordinate value displayed in the Position tool.

4. To determine the offset associated with the original and displayed Z coordinate value, subtract the old value from the new value.

   The resulting value indicates the accuracy of the DSM over that specific check point.

Determining Stereo Model Accuracy—Z Coordinate

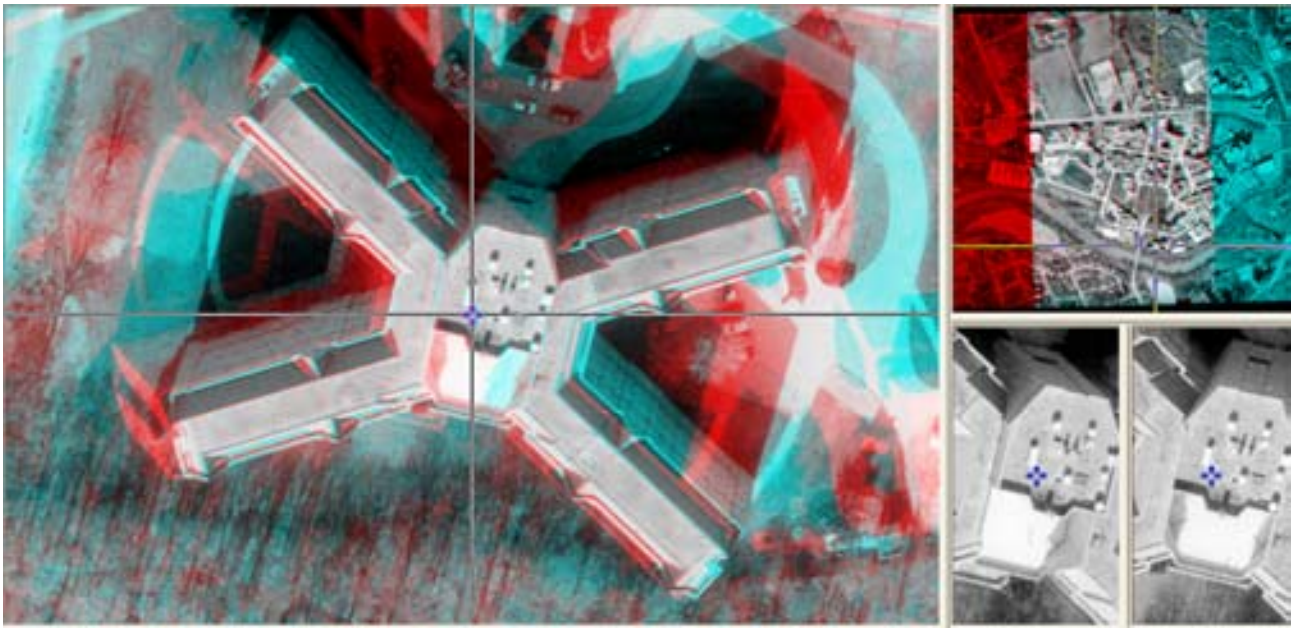
Like the X and Y coordinates, you determine the accuracy of the Z (elevation) coordinate by subtracting your results from the values provided to you.

Original Check Point 1 Z Elevation	New Check Point 1 Z Elevation	Difference
247.24	247.2485	0.0085

Second Check Point

1. Check that **Enable Update** button is not active and the **Zoom** is set to approximately **1.0**.

2. In the Position tool, type the following **X**, **Y**, and **Z** values, respectively: **478067.22**, **4761584.73**, and **259.96**.



3. Position the cursor and visually interpret the location of the 3D floating cursor over the feature.

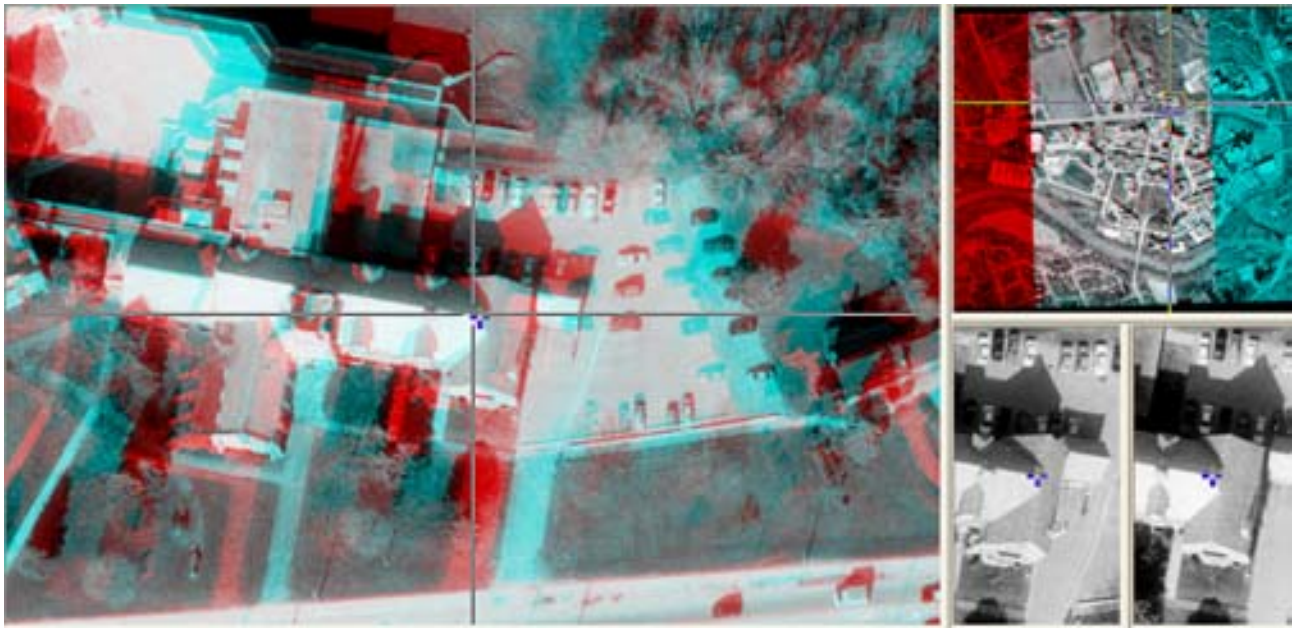
Compute X, Y Coordinate and Z Elevation Accuracy

For more detailed instructions, see "First Check Point".

1. If necessary, adjust the image so that the feature is within the crosshair using the **Enable Update** option in the Position tool.
2. Record the new **X** and **Y** coordinate positions, then subtract the old values from the new values to determine accuracy.
3. If necessary, adjust the height of the cursor.
4. Record the new **Z** coordinate, then subtract the old value from the new value to determine accuracy.

Third Check Point

1. Check that **Enable Update** button is not active and the **Zoom** is set to approximately **1.0**.
2. In the Position tool, type the following **X**, **Y**, and **Z** values, respectively: **477344.68**, **4761657.79**, and **269.99**.



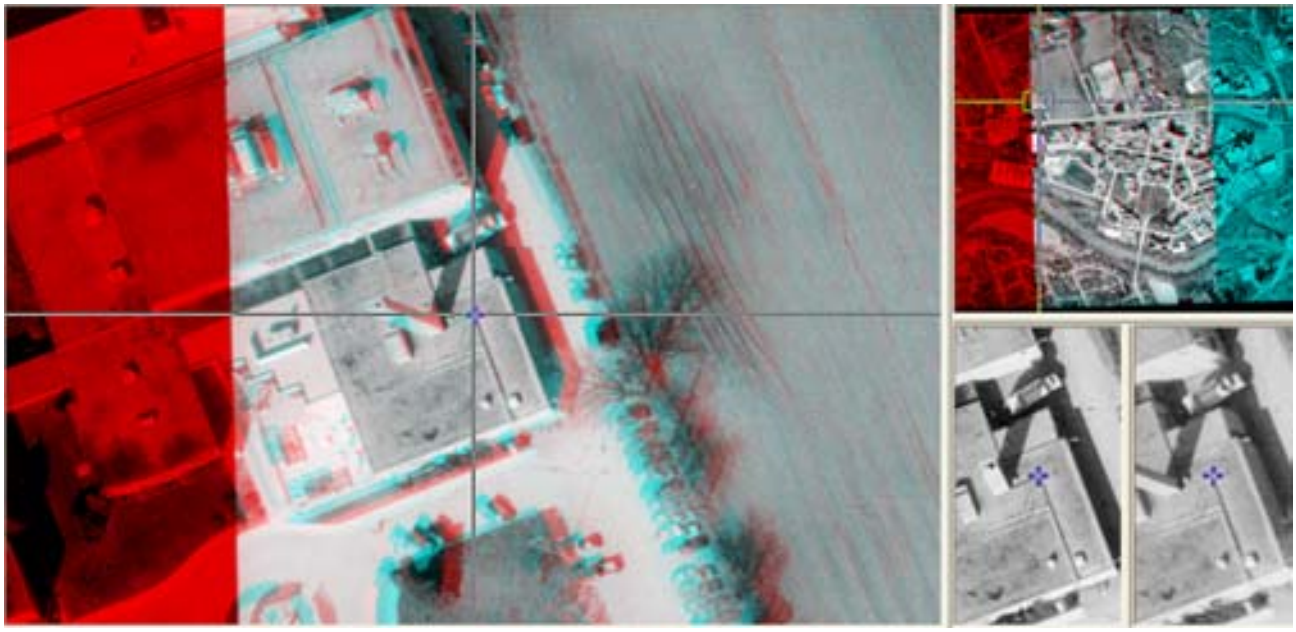
3. Position the cursor and visually interpret the location of the 3D floating cursor over the feature.

Compute X, Y Coordinate and Z Elevation Accuracy

1. If necessary, adjust the image so that the feature is within the crosshair using the **Enable Update** option in the Position tool.
2. Record the new **X** and **Y** coordinate positions, then subtract the old values from the new values to determine accuracy.
3. If necessary, adjust the height of the cursor.
4. Record the new **Z** coordinate, then subtract the old value from the new value to determine accuracy.

Fourth Check Point

1. Check that **Enable Update** button is not active and the **Zoom** is set to approximately **1.0**.
2. In the Position tool, type the following **X**, **Y**, and **Z** values, respectively: **477327.95**, **4760990.42**, and **257.79**.



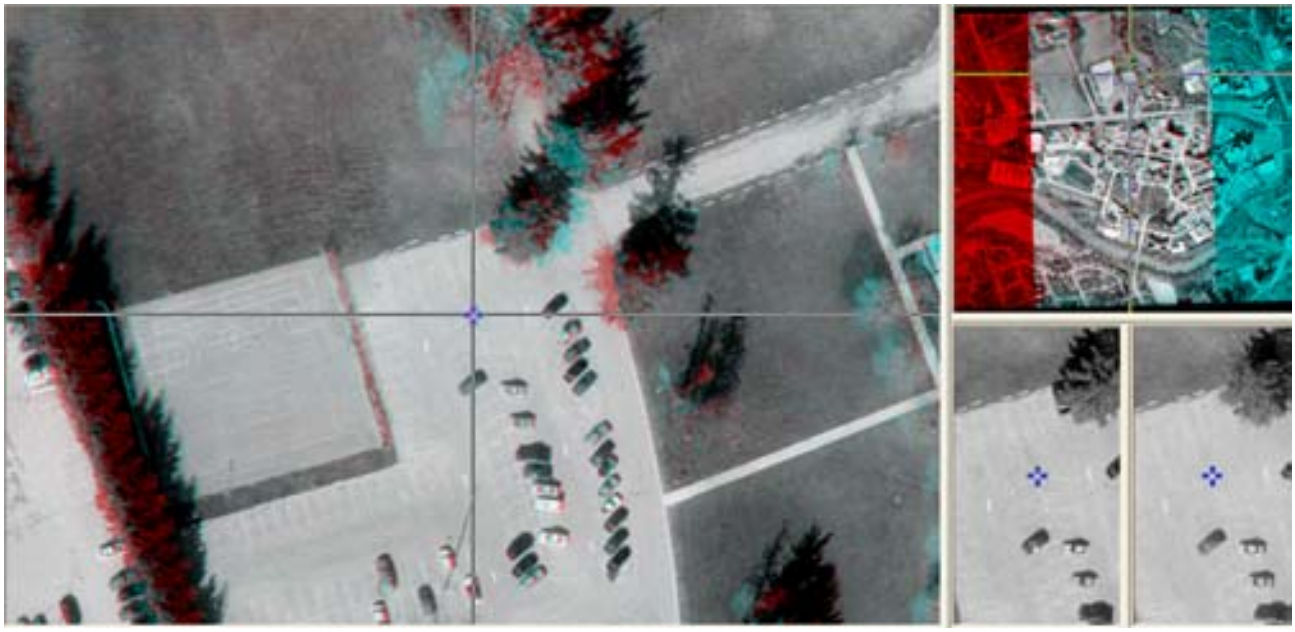
3. Position the cursor and visually interpret the location of the 3D floating cursor over the feature.

Compute X, Y Coordinate and Z Elevation Accuracy

1. If necessary, adjust the image so that the feature is within the crosshair using the **Enable Update** option in the Position tool.
2. Record the new **X** and **Y** coordinate positions, then subtract the old values from the new values to determine accuracy.
3. If necessary, adjust the height of the cursor.
4. Record the new **Z** coordinate, then subtract the old value from the new value to determine accuracy.

Fifth Check Point

1. Check that **Enable Update** button is not active and the **Zoom** is set to approximately **1.0**.
2. In the Position tool, type the following **X**, **Y**, and **Z** values, respectively: **477193.83**, **4761458.69**, and **257.36**.



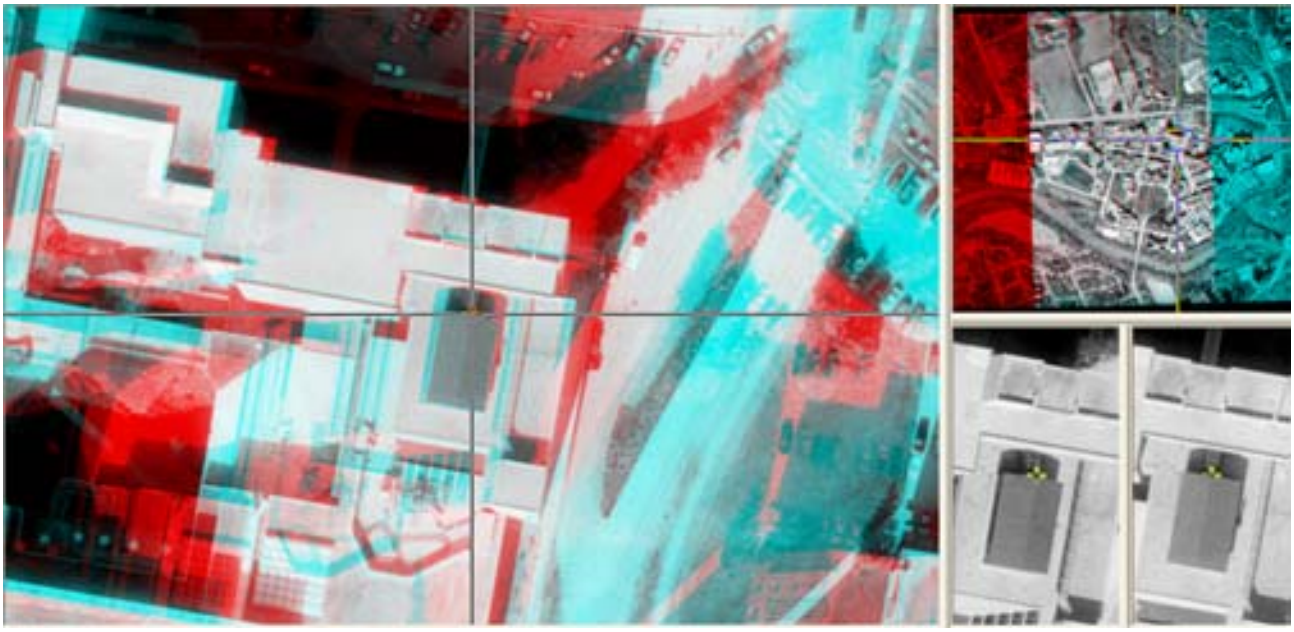
3. Position the cursor and visually interpret the location of the 3D floating cursor over the feature.

Compute X, Y Coordinate and Z Elevation Accuracy

1. If necessary, adjust the image so that the feature is within the crosshair using the **Enable Update** option in the Position tool.
2. Record the new **X** and **Y** coordinate positions, then subtract the old values from the new values to determine accuracy.
3. If necessary, adjust the height of the cursor.
4. Record the new **Z** coordinate, then subtract the old value from the new value to determine accuracy.

Sixth Check Point

1. Check that **Enable Update** button is not active and the **Zoom** is set to approximately **1.0**.
2. In the Position tool, type the following **X**, **Y**, and **Z** values, respectively: **477532.93**, **4761699.51**, and **292.08**.



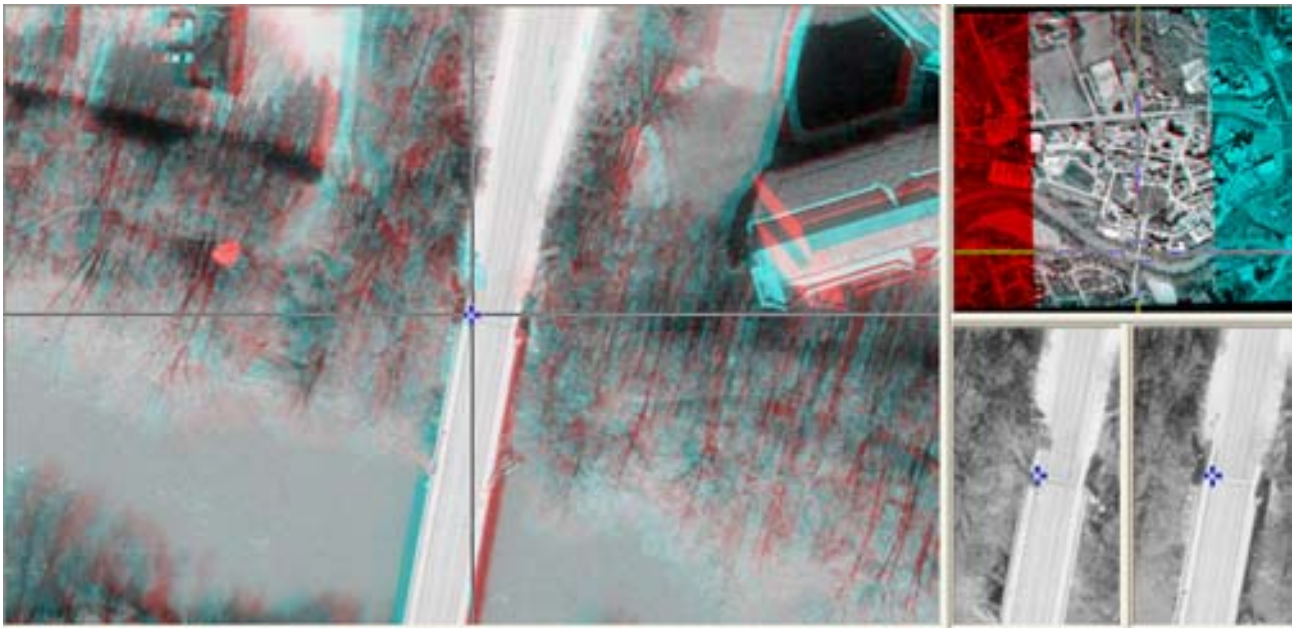
3. Position the cursor and visually interpret the location of the 3D floating cursor over the feature.

Compute X, Y Coordinate and Z Elevation Accuracy

1. If necessary, adjust the image so that the feature is within the crosshair using the **Enable Update** option in the Position tool.
2. Record the new **X** and **Y** coordinate positions, then subtract the old values from the new values to determine accuracy.
3. If necessary, adjust the height of the cursor.
4. Record the new **Z** coordinate, then subtract the old value from the new value to determine accuracy.

Seventh Check Point

1. Check that **Enable Update** button is not active and the **Zoom** is set to approximately **1.0**.
2. In the Position tool, type the following **X**, **Y**, and **Z** values, respectively: **478102.12**, **4761488.28**, and **242.60**.



3. Position the cursor and visually interpret the location of the 3D floating cursor over the feature.

Compute X, Y Coordinate and Z Elevation Accuracy

1. If necessary, adjust the image so that the feature is within the crosshair using the **Enable Update** option in the Position tool.
2. Record the new **X** and **Y** coordinate positions, then subtract the old values from the new values to determine accuracy.
3. If necessary, adjust the height of the cursor.
4. Record the new **Z** coordinate, then subtract the old value from the new value to determine accuracy.

Close the Position Tool

Now that you have checked and recorded the accuracy of the DSM, you can close the Position tool and close the block file, **western_accuracy.blk**.

1. In the Position tool, click the Close icon .

   The Digital Stereoscope Workspace again occupies the entire window.

2. Click the Clear Viewer icon to empty the Digital Stereoscope Workspace.
3. Select **File -> Exit Workspace** to close Stereo Analyst if you wish.

Next

In the next tour guide, you are going to work with another one of the tools you may find in Stereo Analyst: the 3D Measure tool. Using the Measure tool, the following information can be collected:

- 3D point coordinates
- slope and distance and elevation difference between two points
- area
- azimuth along a line
- the angle between three points

Measuring 3D Information

Introduction

The following tour guide describes the techniques associated with measuring 3D information in Stereo Analyst.

Using the 3D Measure tool, the following information can be collected:

- 3D coordinates of a point
- length of a line
- slope of a line
- azimuth of a line
- difference in elevation (Delta Z) between the start point and end point of a line
- area of a polygon
- angle between three points
- average elevation value in a polygon
- average elevation value in a polyline

The 3D Measure tool can be used as an effective aid for airphoto interpretation and quantitative analysis of geographic information. For example, the area boundary of a forest can be delineated and measured in 3D.

Specifically, the steps you are going to execute in this example include:

- Open a block file.
- Select a DSM from the Stereo Pair Chooser.
- Open the 3D Measure tool.
- Measure points, polylines, and polygons in 3D.
- Evaluate the measurement results.
- Save 3D Measure tool results to an ASCII file.

The data used in this tour guide covers the campus of The University of Western Ontario in London, Ontario, Canada. The four photographs were captured at a photographic scale of 1:6000. The photographs were scanned at a resolution of 25 microns. The resulting ground coverage per pixel is 0.15 meters.

Approximate completion time for this tour guide is 1 hour 15 minutes.

You must have both Stereo Analyst and the example files installed to complete this tour guide.

Getting Started

NOTE: This tour guide was created in color anaglyph mode. If you want your results to match those in this tour guide, set your stereo mode to color anaglyph by selecting **Utility -> Stereo Analyst Options -> Stereo Mode -> Stereo Mode -> Color Anaglyph Stereo**.

First, you must launch Stereo Analyst. For instructions on launching Stereo Analyst, see "Getting Started".

Once Stereo Analyst has been started and you have an empty Digital Stereoscope Workspace, you are ready to begin.

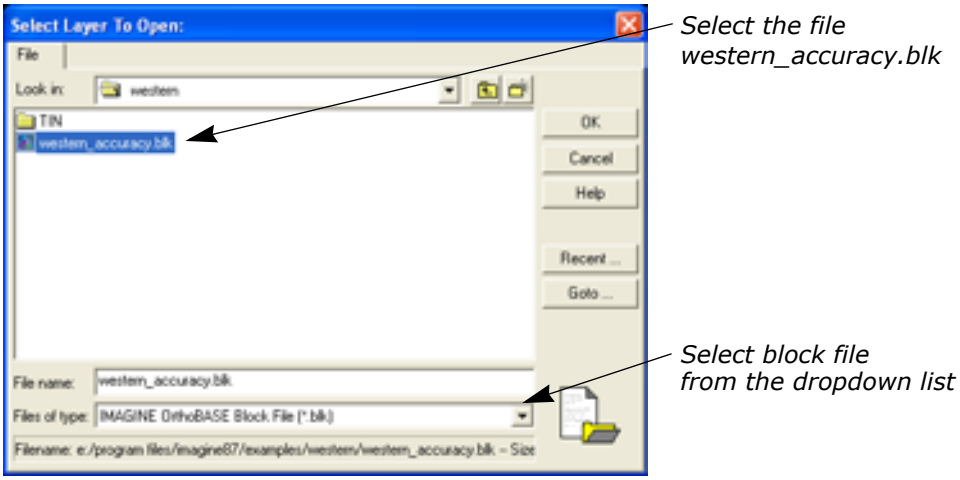
Open a Block File

For the remainder of the tour guide, you need either red/blue glasses or stereo glasses that work in conjunction with an emitter.

First, you open a block file.

1. From the toolbar of the empty Digital Stereoscope Workspace, click the Open icon .

The Select Layer To Open dialog opens. Here, you select the type of file you want to open in the Digital Stereoscope Workspace.



2. Navigate to the <IMAGINE_HOME>/examples/Western directory, then select the file named **western_accuracy.blk**.

   The block file contains all of the necessary information required to automatically create and display a DSM in real-time.

   The block file in this example was created in LPS Project Manager. Camera calibration and GCP information was input and used to calculate all of the necessary sensor model information. The resulting sensor model information is used to calculate and display 3D coordinate information.

   For more information about the workflow required to create a DSM, see "Workflow".

3. Click **OK** in the Select Layer To Open dialog.

   NOTE: If you have not already created pyramid layers for the images in the block file, you are prompted to do so.

   The first DSM associated with the **western_accuracy.blk** file displays in the Digital Stereoscope Workspace once the block file opens.

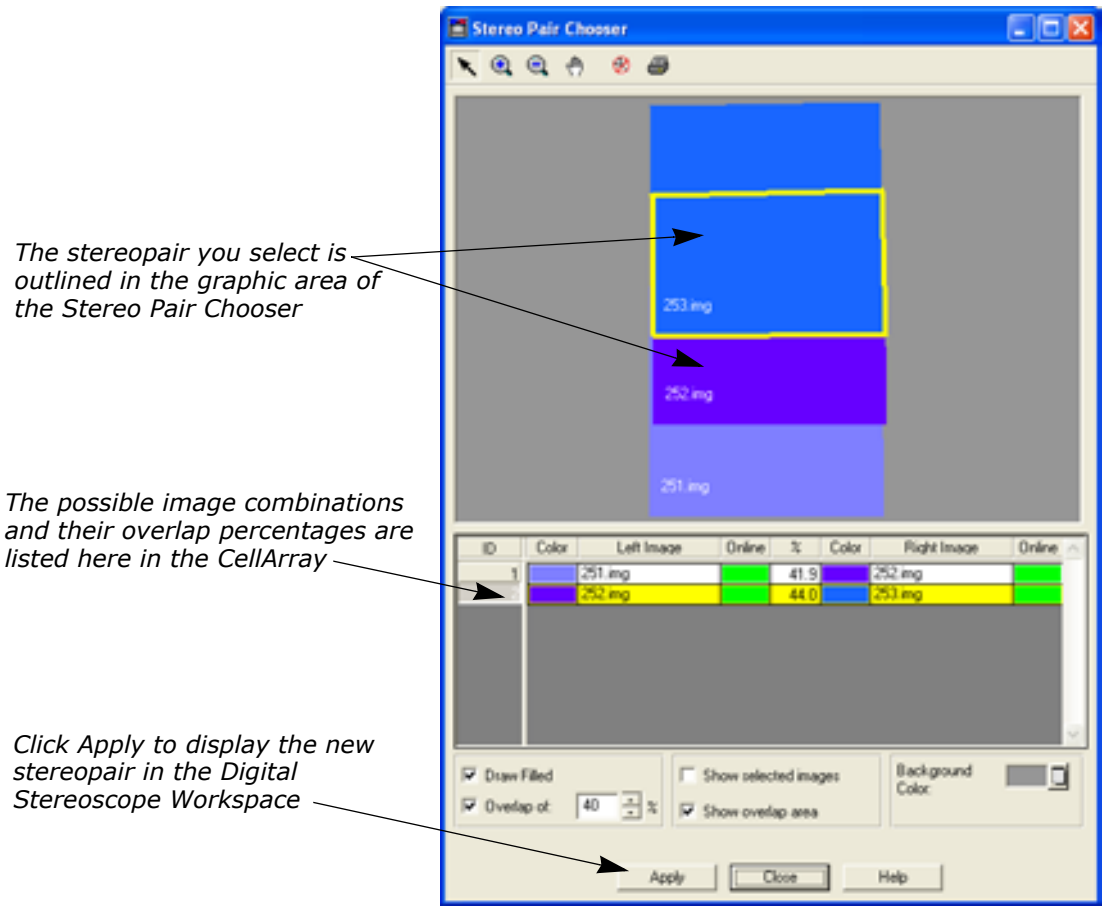
If you wish to view only the overlap area associated with a DSM, you can set an option to achieve that effect. From the **Utility** *menu, select* **Stereo Analyst Options**. *Then, click the* **Stereo View Options** *option category. Click to select the* **Mask Out Non-Stereo Regions** *option.*

Open the Stereo Pair Chooser

You can select various DSMs from the **western_accuracy.blk** file. To do so, you open the Stereo Pair Chooser. With it, you can select stereopairs that suit criteria you specify, such as overlap area.

1. In the Digital Stereoscope Workspace, click the Stereo Pair Chooser icon .

   The Stereo Pair Chooser opens.



The stereopair you select is outlined in the graphic area of the Stereo Pair Chooser

The possible image combinations and their overlap percentages are listed here in the CellArray

Click Apply to display the new stereopair in the Digital Stereoscope Workspace

The Stereo Pair Chooser is equipped with a CellArray. You can use the CellArray to select different DSMs from the block file. These DSMs can then be displayed in the Digital Stereoscope Workspace.

2. Click to select row **2** in the **ID** column. This is the image pair consisting of **252.img** and **253.img**.

   Notice that the highlighted row corresponds to the highlighted portion of the footprint in the Stereo Pair Chooser. You can see the overlap area that is going to be displayed in the Digital Stereoscope Workspace. In this case, you can see that the overlap area is approximately 44%.

   The overlap areas of the image footprints displayed in the Stereo Pair Chooser can also be interactively selected to choose a DSM of interest. Once a DSM has been graphically selected, the corresponding DSM displays in the CellArray.

3. Click **Apply** in the Stereo Chooser.

   The new DSM displays in the Digital Stereoscope Workspace.

4. Click **Close** in the Stereo Chooser.

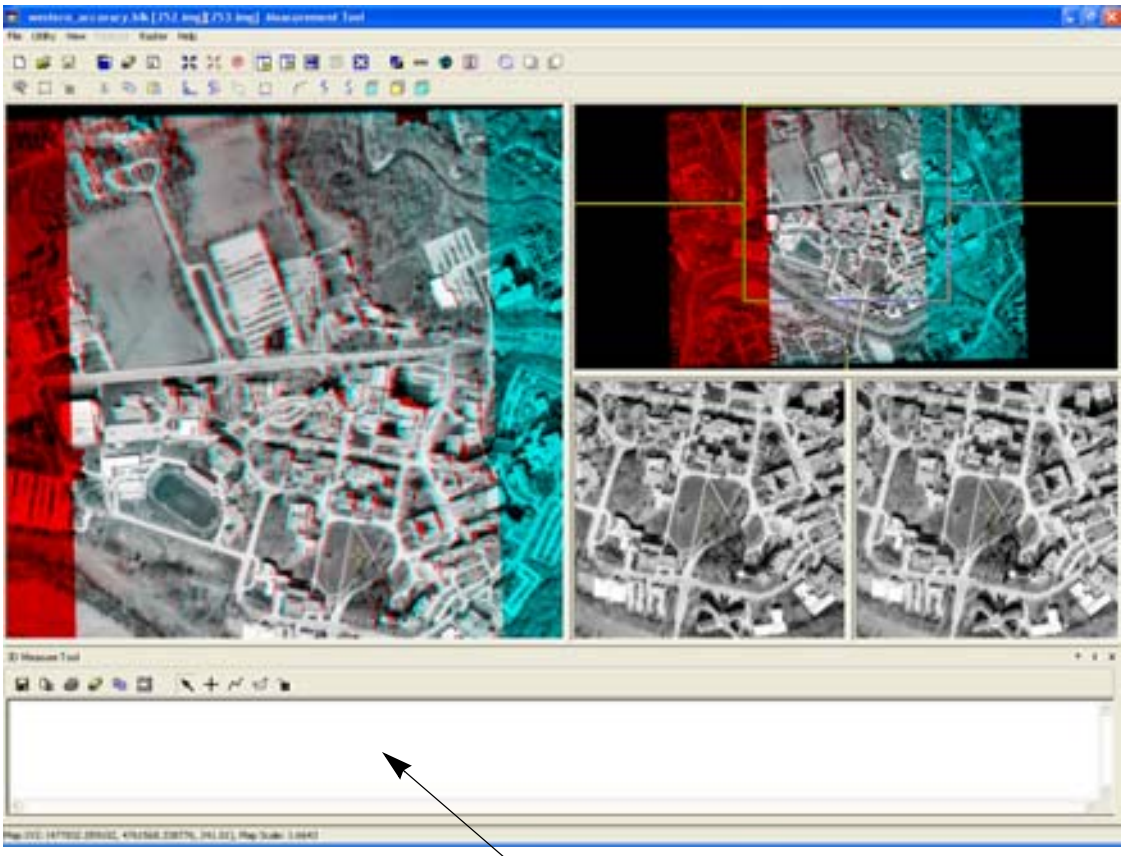
Take 3D Measurements

Now that you have the DSM displayed, you can use some of the other Stereo Analyst tools to take measurements of buildings, roads, and other features in the DSM. In this portion of the tour guide, you are going to work with the 3D Measure tool to measure features contained in a DSM.

Open the 3D Measure Tool and the Position Tool

1. With the stereopair **252.img** and **253.img** displayed in the Digital Stereoscope Workspace, click the 3D Measure tool icon .

   The 3D Measure tool occupies the bottom portion of the Digital Stereoscope Workspace.



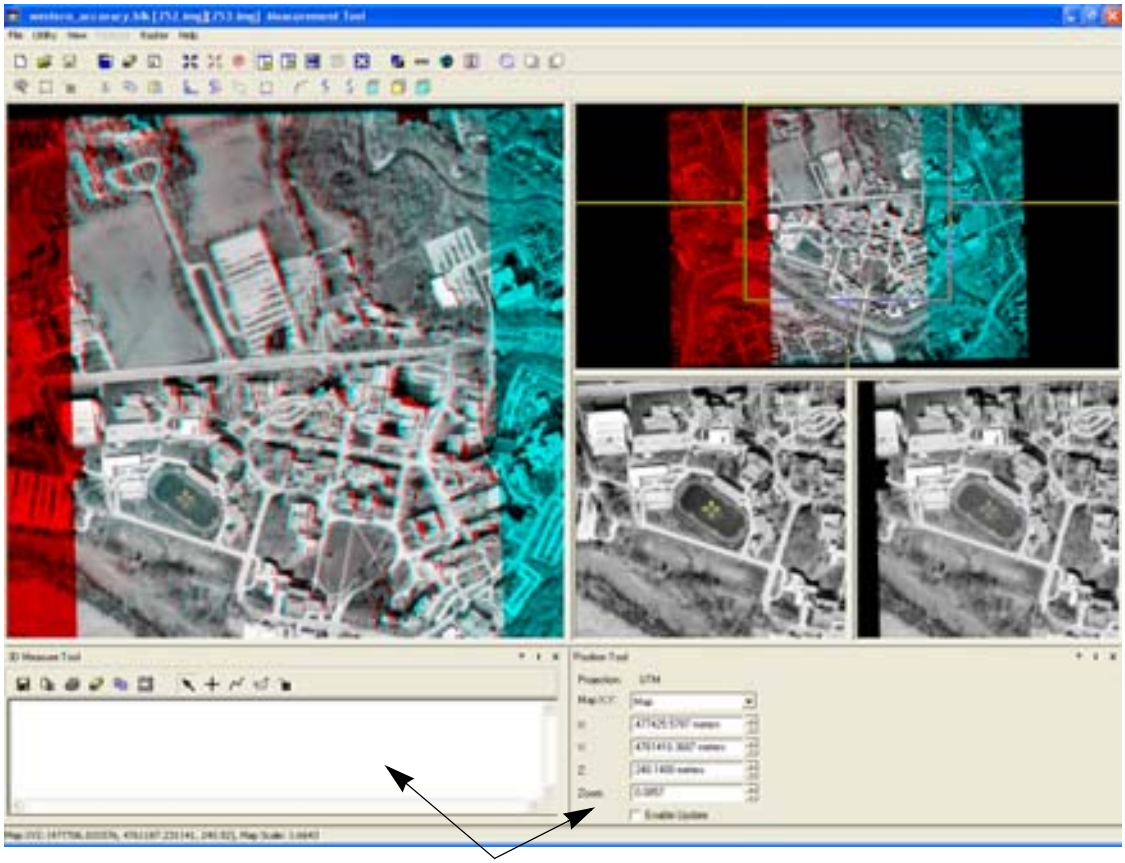
Tools you open display at the bottom of the Digital Stereoscope Workspace

Since you have used the Position tool in the previous tour guide, you are familiar with entering 3D coordinates into it to drive to certain locations in the DSM. Next, you can use the Position tool to drive to areas in the stereopair, and then take measurements with the 3D Measure tool.

2. Click the Position tool icon .

   The Position tool occupies the lower half of the Digital Stereoscope Workspace along with the 3D Measure tool.

If you would rather have the tools display horizontally, click the *icon located in the upper right corner of each tool.*



The Digital Stereoscope Workspace adjusts to accommodate both tools

You may find the terrain following cursor helpful in completing this exercise.

Terrain Following Cursor

The terrain following cursor is one of the utilities in Stereo Analyst that you can toggle on and off. When the utility is on, there is no need to manually adjust the height of the cursor to meet the feature of interest via the mouse. In this mode, the 3D floating cursor identifies the position of a feature appearing in the stereopair and automatically adjusts the height of the 3D floating cursor so that it always rests on top of the point of interest. You can access it via the **Utility** menu or via the right mouse button.

Take the First Measurement

The first measurement you are going to take is the length of a sidewalk.

Enter the 3D Coordinates

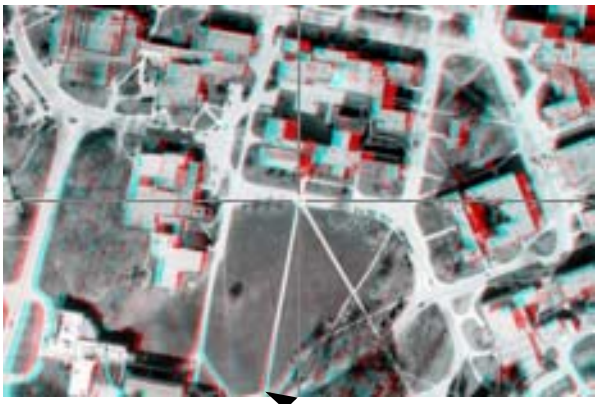
1. In the **X** field of the Position tool, type **477759.50**.
2. In the **Y** field of the Position tool, type **4761557.36**.
3. In the **Z** field of the Position tool, type **251.99**.

Digitize the Polyline

Stereo Analyst drives to the 3D coordinate position you specify.

1. Position your cursor at the intersection of the crosshair, and zoom into the area by pressing down the mouse wheel (or middle mouse button) and moving the mouse away from you.

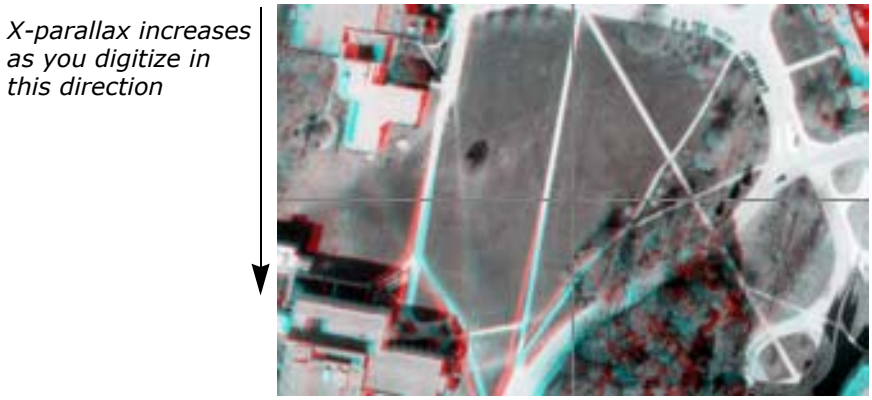
   NOTE: After zooming in, the point you entered in the Position tool may not be under the crosshair. You may need to re-enter the coordinates to see the exact location under the crosshair.



Digitize this sidewalk

This particular sidewalk has a good deal of slope to it. Before you begin measuring, zoom out to get a full picture of the sidewalk.

2. Click and hold the wheel and zoom out of the image until the entire sidewalk can be seen in the Main View.



Notice that, as you travel southward along the sidewalk, the x-parallax increases. Remember, x-parallax is a function of elevation. Once you begin to digitize in those areas, you have to adjust the 3D floating cursor so that it rests on the terrain while the measurements are being taken.

Now that you have examined the sidewalk you are about to digitize, you can take a measurement. In the next series of steps, you are going to take a measurement using the Polyline tool.

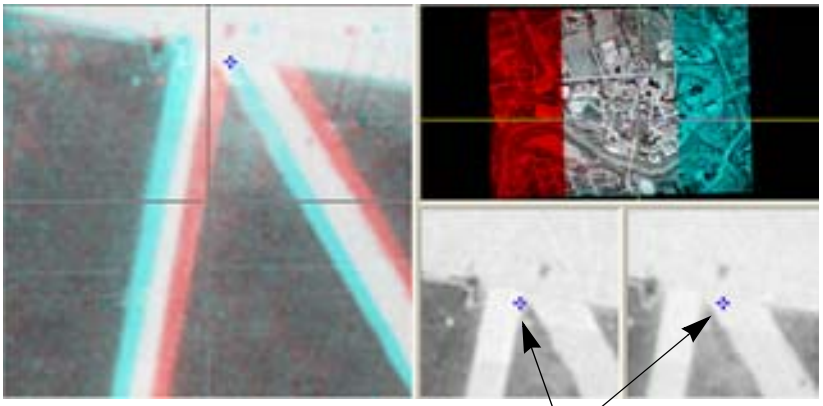
For information about adjusting the height of the cursor to rest on a particular feature of interest, see "Cursor Height Adjustment" on page 105.

3. Click in the 3D Measure tool and select the Polyline tool .

The Polyline tool allows for the continuous 3D collection of line segments. Each vertex associated with the start and end of a line segment (as well as all those in-between) has a 3D coordinate associated with it. The slope, azimuth, and difference in elevation between the start and end of a line segment are also recorded.

4. Move your mouse into the Main View, click and hold the wheel, and zoom into the northern point of the sidewalk.

Notice that, as you zoom into the origin of the sidewalk, the cursor appears to separate. This means that the cursor is not positioned on the ground. Also, if you look at the Left and Right Views containing the left and right images of the DSM, you see that the cursor does not appear to be in the same geographic location in both images.



NOTE: The optimum zoom rate for collecting 3D measurement for this particular area of interest is **1.5***. You can enter this value in the Position tool.*

5. Adjust the height of the 3D floating cursor so that the cursor rests on the ground.

NOTE: This does not affect the selection of the Polyline tool.

If you do not have a mouse equipped with a wheel, you can hold the **C** *key on the keyboard, as you simultaneously hold the left mouse button. Then, move the mouse forward and away from or backwards and toward you to adjust elevation.*

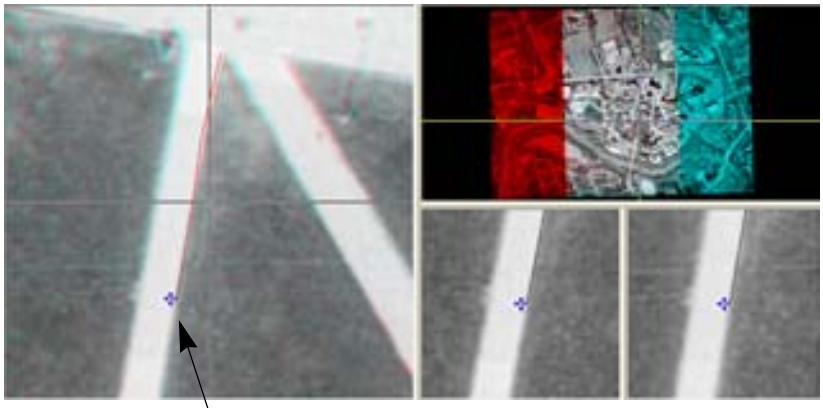
6. Click the left mouse button to digitize the first vertex associated with the polyline.

7. Move vertically along the sidewalk and continue to click to place vertices along the edge of the sidewalk.

NOTE: Ensure that the 3D floating cursor rests on the ground at each point of measurement.

NOTE: As you approach the display extent of the Main View, the image automatically roams so that you can continue digitizing. The area outside the visible space is called the autopan buffer. Stereo Analyst recognizes when your cursor is in the autopan buffer, and adjusts the stereopair in the view accordingly.

Within a short distance, you notice that the x-parallax is not optimal. In order to get an accurate measurement, you need to adjust the x-parallax and cursor elevation again.



As you digitize here, check the monoscopic views to see that the cursor is on the same feature in both of the images

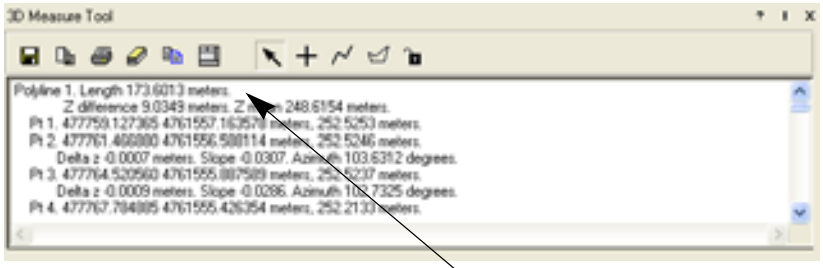
8. Adjust the x-parallax and cursor elevation as necessary, and continue digitizing the sidewalk.

   NOTE: The digitizing line seems to disappear while you adjust x-parallax. It reappears as you continue collecting vertices.

9. Double-click to stop digitizing the sidewalk.

Evaluate Results

Once you stop digitizing, the results of the measurements are displayed in the 3D Measure tool.



Length is listed first

Now that you have finished digitizing the polyline, you can evaluate the 3D measurements.

NOTE: The measurements of the polyline you digitized may differ from those digitized in this tour guide.

1. Use the scroll bar to see the first line displayed in the 3D Measure tool text field:

   `Polyline 1. Length 173.6013 meters`

   This means that the length of the entire segment of sidewalk you digitized is approximately 173 meters long.

2. Notice the second line:

`Z difference 9.0349 meters. Z mean 248.6154 meters.`

This means that the elevation change between the first point and the last point, **Z difference**, is approximately 9 meters. The average elevation of the polyline, **Z mean**, is approximately 249 meters.

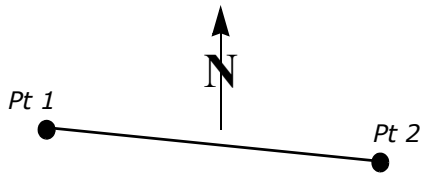
NOTE: The 3D coordinates associated with the starting point of the polyline are displayed as Pt 1.

3. Notice the statistics for **Pt 2**. (in this example):

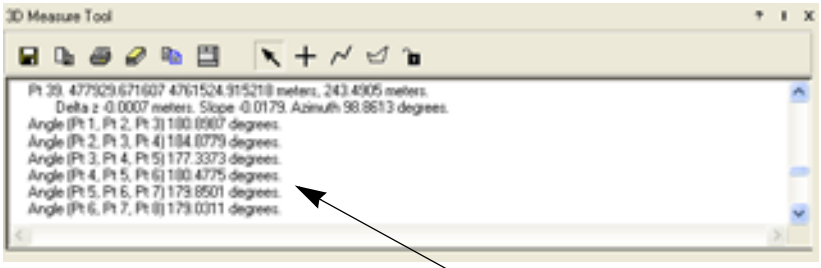
   `Pt 2. 477761.466880 4761556.588114 meters, 252.5246 meters.`

   `Delta z -0.0007 meters. Slope -0.0307. Azimuth 103.6312 degrees.`

   These statistics give the X and Y coordinates and Z in meters for the second vertex associated with the polyline. The Delta z value is the difference in elevation between Pt 1 and Pt 2. Slope is computed as the difference in elevation between two points (that is, Delta Z), divided by the distance between the same two points. Azimuth is the direction of a line segment relative to North. Refer to the following figure. In this case, the azimuth would be approximately 90°.



4. Scroll down to the end of the **Pt** measurements to reach the **Angle** measurements.



Angle measurements are listed after the point measurements

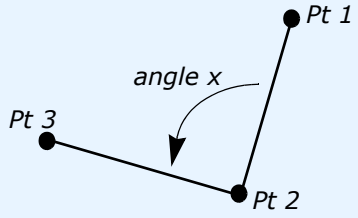
5. Use the scroll bar to see the first **Angle** measurement:

   `Angle (Pt 1, Pt 2, Pt 3) 180.8987 degrees.`

Reading Angle Measurements

NOTE: The angles measured are always counterclockwise.

To understand the meaning of this measurement, consult the following diagram:



The measurement displays in the 3D Measure tool as follows:

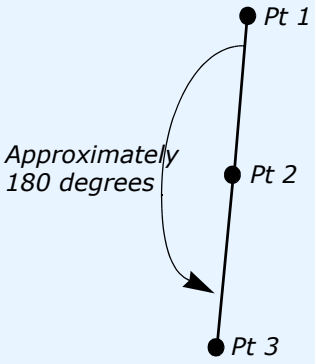
`Angle (Pt 1, Pt 2, Pt 3) 180.8592 degrees`

where (Pt 1, Pt 2, Pt 3) is the "list".

The line is translated as follows:

At **Pt 2** (the central point in the list), the angle from **Pt 1** to **Pt 3** (left to right in the list) is **180.8592** degrees.

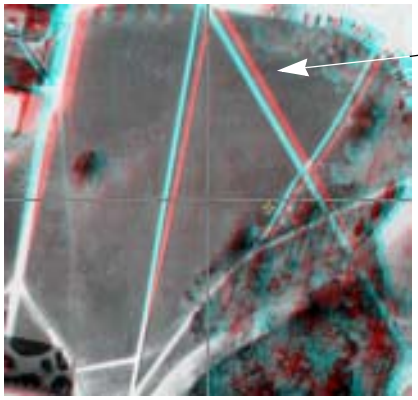
The angle is reported in decimal degrees, and is graphically represented as follows:



View the Digitized Line

You can zoom out and see the line you just digitized in the Main View. You can see double lines due to x-parallax and the change in elevation as you digitized the sidewalk.

1. Click and hold the wheel while moving the mouse toward you to zoom out.
2. Zoom out until the entire sidewalk you have just digitized displays in the Main View.
3. Using the left mouse button, adjust the image in the Main View until the entire sidewalk is visible.



Take the Second Measurement

Now that you know how to digitize a polyline, move to a different area of the stereopair and collect another.

Enter the 3D Coordinates

1. Click the Zoom 1:1 icon .
2. In the Position tool, click in the **X** field and type **477696.18**.
3. In the **Y** field, type **4761404.26**.
4. In the **Z** field, type **248.38**.

Digitize the Polyline

Stereo Analyst drives to the 3D coordinate position you specify. The road (as illustrated in the figure below), like the sidewalk you just digitized, has a good deal of slope to it as you move southward.

1. Click in the 3D Measure tool and select the Polyline tool .
2. Position your 3D floating cursor at the top of the bend in the road (indicated with a circle in the previous illustration).

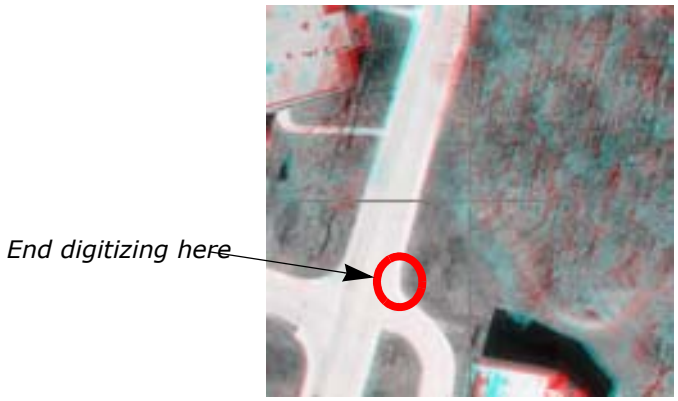
3. Adjust the 3D floating cursor elevation and parallax as required so that it rests on the road.

4. Digitize southward along the road.

   NOTE: Remember to correct x-parallax and cursor elevation as you digitize.

5. Digitize to the next bend in the road (indicated with a circle in the following illustration):

   NOTE: The coordinates of this point are approximately 477829.04, 4761339.82, and 241.37.



6. Once you have finished digitizing the road, double-click to terminate the polyline.

Evaluate Results

The measurements are reported in the text field of the 3D Measure tool.

NOTE: Your results will likely differ from those presented here.

1. Use the scroll bar to see the first line of data associated with the polyline you just digitized, **Polyline 2**:

   `Polyline 2. Length 162.5347 meters.`

   Once again, this is the total length of the line segments comprising the polyline.

2. Notice the second line of data:

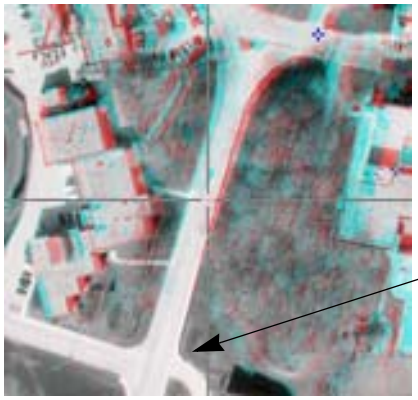
   `Z difference 7.2846 meters. Z mean 246.6845 meters.`

3. Continue to scroll down to view the rest of the results in the 3D Measure tool text field.

View the Digitized Line

You can zoom out and see the line you just digitized in the Main View. You can see double lines due to the change in x-parallax and elevation along the street edge.

1. Click and hold the wheel while moving the mouse toward you to zoom out.
2. Zoom out until the entire road you have just digitized displays in the Main View.
3. Using the left mouse button, adjust the image in the Main View until the entire road is visible.



Since you made adjustments as you collected points, the parallax improves where you finished digitizing

Take the Third Measurement

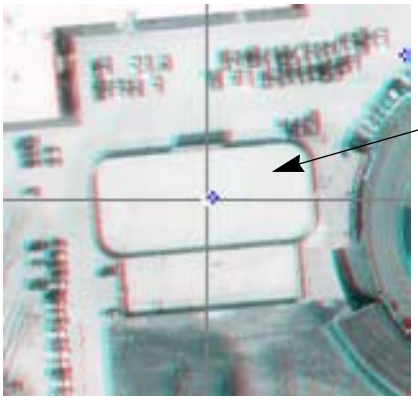
Next, you are going to measure an ice rink using the Polygon tool.

Enter the 3D Coordinates

1. Click the Zoom 1:1 icon .
2. In the Position tool, double-click in the **X** field and type **477677.91**.
3. In the **Y** field, type **4761070.12**.
4. In the **Z** field, type **242.98**.

Digitize the Polygon

Stereo Analyst drives to the 3D coordinate position you specify.

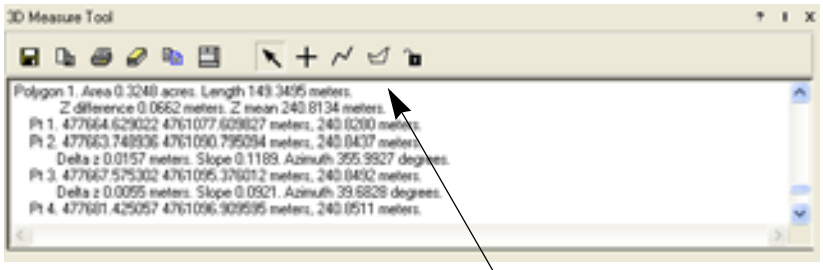


1. If required, adjust the x-parallax to get a clear 3D stereo view.
2. In the 3D Measure tool, click to select the Polygon tool .
3. Position your cursor at one corner of the ice rink, adjust the 3D floating cursor until it rests on the top of the ice rink edge.

   NOTE: The optimum zoom rate for measuring information in this portion of the image is approximately **1.3***. You can enter this value into the Position tool.*
4. Click to digitize the first vertex.
5. Continue to digitize around the perimeter of the ice rink, adjusting the 3D floating cursor as necessary.
6. Once you have finished digitizing the ice rink, double-click to close the polygon.

Evaluate Results

The measurements are reported in the text field of the 3D Measure tool.



This feature is identified as a polygon

NOTE: Your results may differ from those presented here.

1. Use the scroll bar to see the first line of data associated with the polyline you just digitized, **Polygon 1**.

```
Polygon 1. Area 0.3248 acres. Length 149.3495 meters.
```

This means that the area of the ice rink is approximately .3 acres, or 3,553 square feet (1 acre has 43,560 square feet). The length around its perimeter is approximately 149 meters.

2. Notice the second line of data:

```
Z difference 0.0662 meters. Z mean 240.8134 meters.
```

This means that there was approximately a .0662-meter difference between the highest point on the ice rink that you measured and the lowest.

3. Continue to scroll down to view the rest of the results in the 3D Measure tool text field. You get results for each of the points you digitized to create the ice rink.

Take the Fourth Measurement

Next, you are going to digitize a field using the Polygon tool.

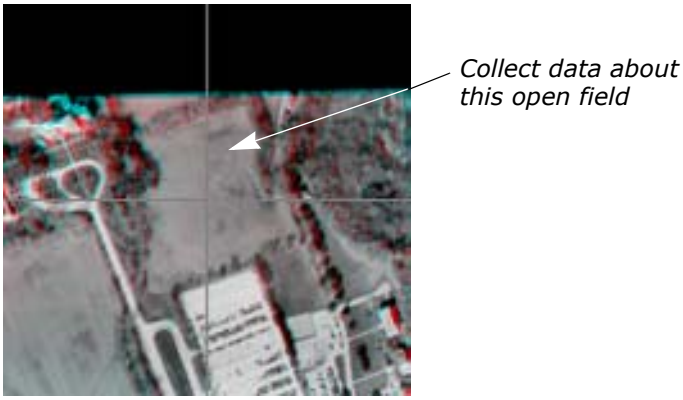
Enter the 3D Coordinates

1. Click the Zoom to Full Resolution icon .
2. In the Position tool, click in the **X** field and type **477018.51**.
3. In the **Y** field, type **4761296.26**.
4. In the **Z** field, type **253.36**.

Digitize the Polygon

Stereo Analyst drives to the 3D coordinate position you specify. This wide field has a unique shape.

1. Position the cursor within the crosshair and use the wheel to zoom in until the field is visible in the Main View.



2. Adjust the x-parallax and cursor elevation as necessary to obtain an optimum 3D stereo view.

3. Click the Polygon tool in the 3D Measure tool.

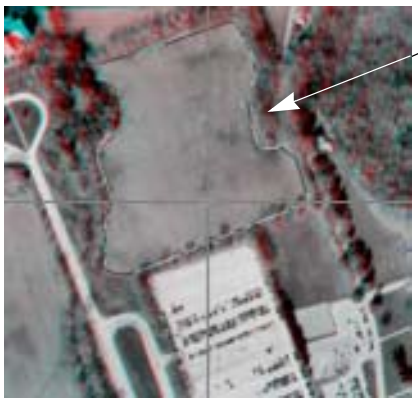
4. Position your cursor at one corner of the field, and click to digitize the first vertex.

5. Continue to digitize around the perimeter of the field, adjusting x-parallax and cursor elevation as necessary.

6. Once you have finished digitizing the field, double-click to close the polygon.

7. Zoom out by holding the wheel and moving the mouse toward you to see the entire polygon.

   Your digitized field should look similar to the following:



The polygon border representing the open field displays after digitizing

Evaluate Results

The measurements are reported in the text field of the 3D Measure tool.

NOTE: Your measurements may differ from those presented here.

1. Use the scroll bar to see the first line of data associated with the polyline you just digitized, **Polygon 2**:

   ```
   Polygon 2. Area 9.0418 acres. Length 844.9017 meters.
   ```

2. Notice the second line of data:

   ```
   Z difference 4.2958 meters. Z mean 256.9078 meters.
   ```

   Continue to scroll down to view the rest of the results in the 3D Measure tool text field. You get results for each of the points you digitized to create the field boundary.

Take the Fifth Measurements

Another tool you can use to measure 3D information is the Point tool. With it, you can measure individual points in a DSM. This technique is especially useful if you are attempting to collect 3D point positions to be used for creating a DEM. In this section of the tour guide, you are going to collect some points along the roof line of a building to see how its elevation changes.

3D Measurement Uses

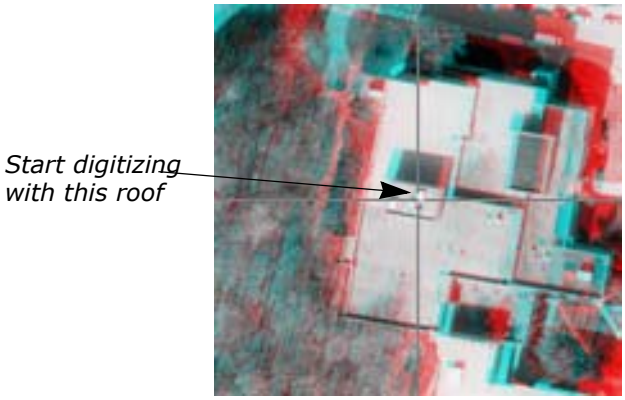
Measuring 3D point positions with the 3D Measure tool is advantageous for collecting information in specific geographic areas where automated techniques fail. This includes floodplains, drainage networks, dense urban areas, forested areas, and road and highway networks including bridges. This approach is also beneficial for collecting 3D information in areas which are normally not accessible by a field survey team. Thus, using Stereo Analyst, highly accurate 3D point positions can be collected in an office environment.

Enter the 3D Coordinates

1. Click the Zoom 1:1 icon .
2. In the Position tool, double-click in the **X** field and type **477745.03**.
3. In the **Y** field, type **4761435.21**.
4. In the **Z** field, type **268.25**.

Digitize the 3D Positions

Stereo Analyst drives to the 3D coordinate position you specify. The roof of this building is divided into many sections and elevations. You can begin digitizing roof corners at the topmost roof: the one that houses the heating and air conditioning equipment.



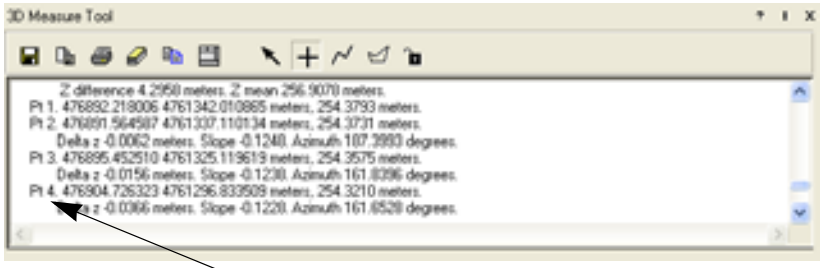
1. Adjust the x-parallax and the 3D cursor elevation as necessary.
2. In the 3D Measure tool, click to select the Points tool .
3. Click the Unlock icon so that it becomes the Lock icon .
   You can then collect consecutive 3D points.

4. Position your cursor at one corner of the roof that houses the utility equipment.
5. Adjust the x-parallax and cursor elevation as necessary.
6. Click to digitize the first corner.
7. Continue to digitize the corners of the roof.

   NOTE: Ensure that the 3D floating cursor is positioned on the feature of interest during the collection of 3D point positions.
8. Move to another roof section, adjust the x-parallax and cursor elevation.
9. Click to digitize the corners of that roof.
10. Continue to move to different sections of the roof, digitizing the corners, until you have digitized all the corners of the entire roof.

Evaluate Results

As the roof corners are digitized, the measurements are reported in the text field of the 3D Measure tool.



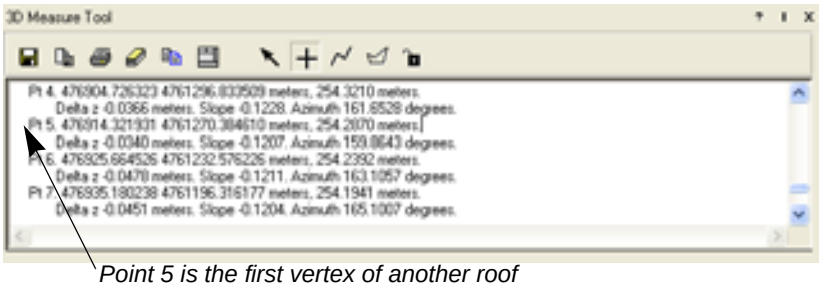
Point features are listed sequentially

NOTE: Your results may differ from those presented here.

1. Use the scroll bar to see the first line of data associated with the polyline you just digitized, **Point 1**:

   `Pt 1. 476892.218006 4761342.010865 meters, 254.3793 meters.`

   This means that Point 1 has an approximate elevation of 267 meters. Notice that the subsequent three points, all part of the same roof, have similar elevations.



Point 5 is the first vertex of another roof

2. Use the scroll bar to see the fifth line of data, **Point 5**:

   `Pt 5. 476914.321931 4761270.384610 meters, 254.2870 meters.`

   This means that the elevation between the various points on the roof changed by less than a meter.

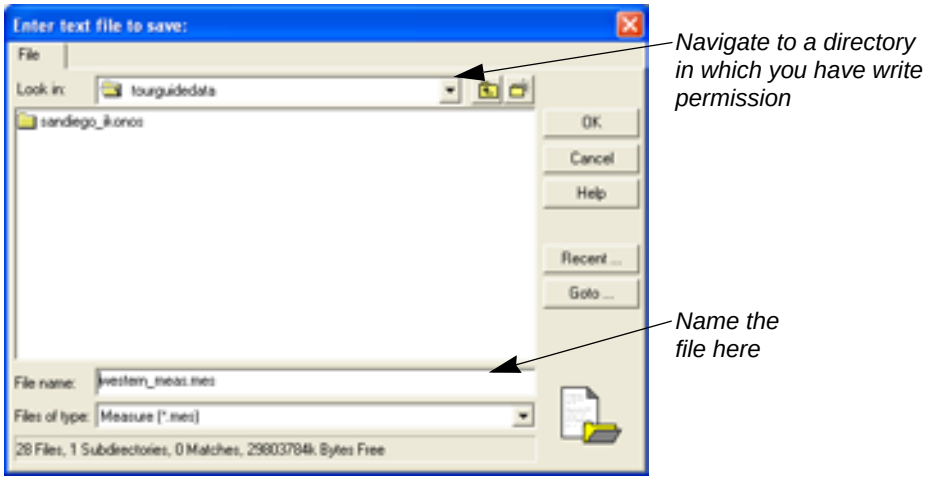
3. Continue to scroll down to view the rest of the results in the 3D Measure tool text field.

You can also use the Terrain Following Cursor to improve the accuracy of your Z, elevation, measurements.

Save the Measurements

You can save the measurements to a text file for use in other applications and products.

1. In the 3D Measure tool, click the Save icon .
2. Navigate to a directory where you have write permission.
3. In the Enter text file to save dialog, click in the **File name** section.



4. Type the name **western_meas**, then press Enter on your keyboard. The .mes file extension is automatically appended.

5. Click **OK** in the Enter text file to save dialog.

   You can now access the file any time you like for use in other applications.

> ***What can you do with an .mes file?***
>
> Using a .mes file that you create with the Stereo Analyst 3D Measure tool, you can import the data into other products for various applications.
>
> For example, if 3D point positions along a river bank have been collected, the information can be used to create a DEM for that specific area of interest. The DEMs generated for the successive time periods can be statistically compared to determine rates of erosion and deposition and the change in volume. If photography for various time periods is available, the same river bank area can be viewed and collected in 3D.

6. Click the Clear View icon to clear the Digital Stereoscope Workspace.

Next

In the next tour guide, you are going to use all of the techniques you have learned in the previous tour guides to collect features from a DSM.

Collecting and Editing 3D GIS Data

Introduction

In the previous tour guides, you have learned about the basic elements of Stereo Analyst. You have learned how to open DSMs in the Digital Stereoscope Workspace and manipulate them so that they can be viewed in stereo. You have also learned how to adjust parallax and cursor elevation. You can now create your own block files using information from external sources. Also, you can check block files to ensure their accuracy using check points. Finally, you learned how to collect 3D information from a DSM.

You are going to use these techniques in order to collect features from a DSM. This tour guide shows you how to use the tools provided by Stereo Analyst to simplify feature collection.

Specifically, the steps you are going to execute in this example include:

- Create a new feature project.
- Create a custom feature class.
- Collect building features using collection tools.
- Collect roads and related features using collection tools.
- Collect a river feature using collection tools.
- Use the Stereo Pair Chooser.
- Collect a forest feature using collection tools.
- Check the attribute tables.
- Use selection criteria on attribute tables.

The data used in this tour guide covers the campus of The University of Western Ontario in London, Ontario, Canada. The photographs were captured at a photographic scale of 1:6000. The photographs were scanned at a resolution of 25 microns. The resulting ground coverage per pixel is 0.15 meters.

You may want to refer to the feature collecting tools reference and the feature editing tools reference in the Stereo Analyst On-Line Help for tips on collecting and editing features.

Approximate completion time for this tour guide is 2 hours.

You must have both Stereo Analyst and the example files installed to complete this tour guide.

Getting Started

This tour guide was created in color anaglyph mode. If you want your results to match those in this tour guide, set your stereo mode to color anaglyph by selecting **Utility -> Stereo Analyst Options -> Stereo Mode -> Stereo Mode -> Color Anaglyph Stereo.**

First, you must launch Stereo Analyst. For instructions on launching Stereo Analyst, see "Getting Started".

Once Stereo Analyst has been started and you have an empty Digital Stereoscope Workspace, you are ready to begin.

Create a New Feature Project

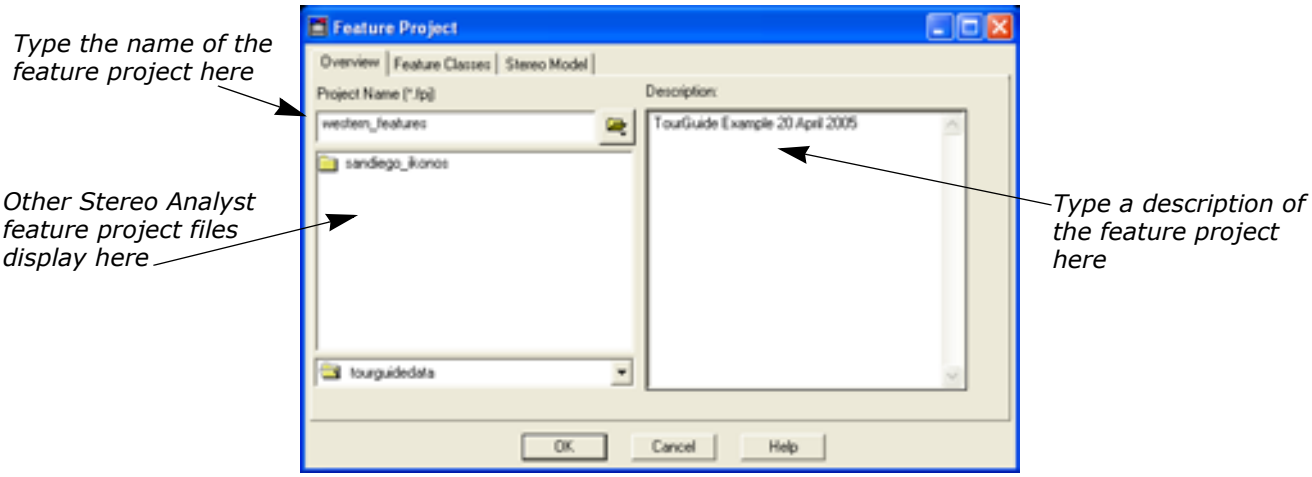
The first step in collecting features from a DSM involves setting up the new Digital Stereoscope Workspace.

1. From the **File** menu of the empty Digital Stereoscope Workspace, select **New -> Stereo Analyst Feature Project**.

   The Feature Project dialog opens. In this dialog, you select the properties of your feature project including name, classes, and the associated DSM.

Enter Information in the Overview Tab

To create a Feature Project, the first tab you enter information into is the **Overview** tab.



1. Navigate to a directory where you have write permission.

By default, the Feature Project dialog opens in the directory you set as your **Output Directory** *in the* **User Interface & Session** *preferences.*

2. Click in the **Project Name** field of the **Overview** tab and type the name **western_features**, then press Enter on your keyboard.

3. Click in the **Description** field and type **Tour Guide Example**, and the current date.

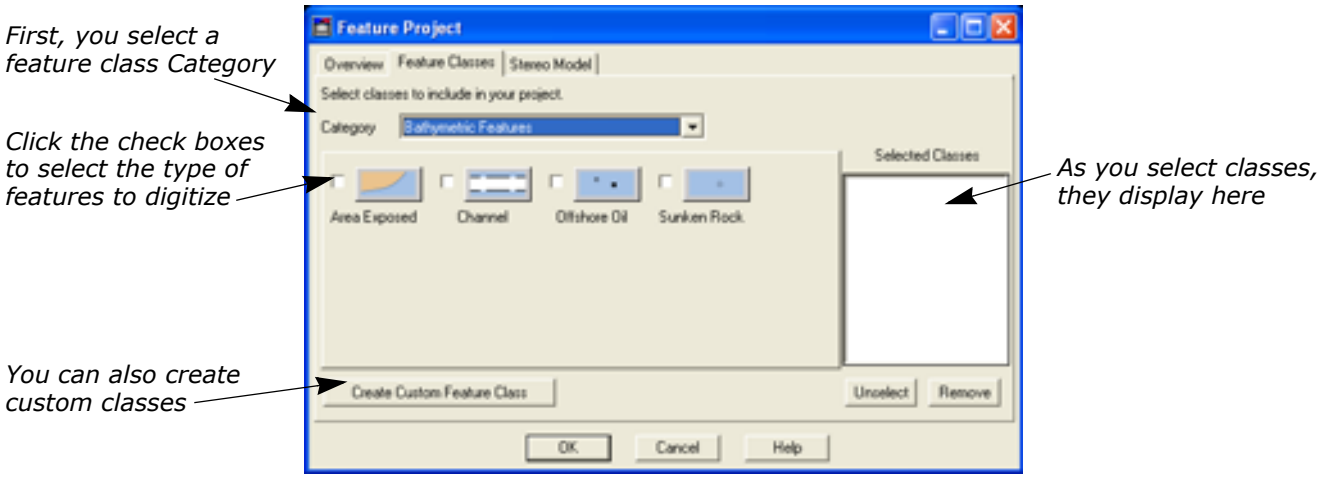
Enter Information in the Features Classes Tab

In the **Features Classes** tab, you are able to select the specific features you wish to digitize in the DSM. As you can see in the following series of steps, the **Feature Classes** tab is neatly divided into types of features (for example, water, buildings, and streets), which better enables you to select specific feature types you want.

If you edit feature class properties in a feature project, the next time you save the project, you are prompted as to whether or not you want to save the display properties and attributes changes to the global feature class. If you select Yes, the global feature class is permanently altered. If you select No, then the display properties and attributes changes are only saved to the feature class in the current project.

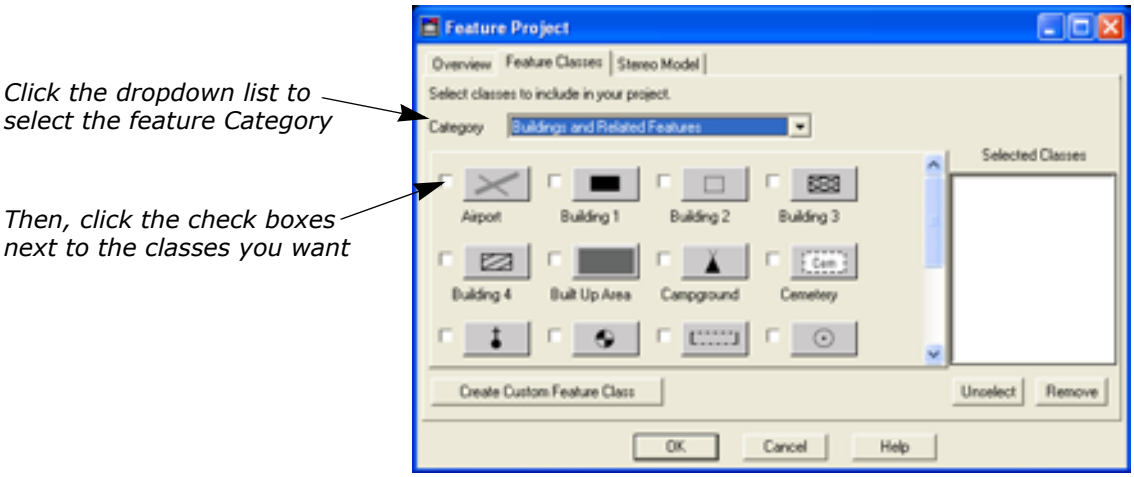
1. In the Feature Project dialog, click the **Feature Classes** tab.

   The various features available to you display in the **Feature Classes** tab.



Select Buildings and Related Features

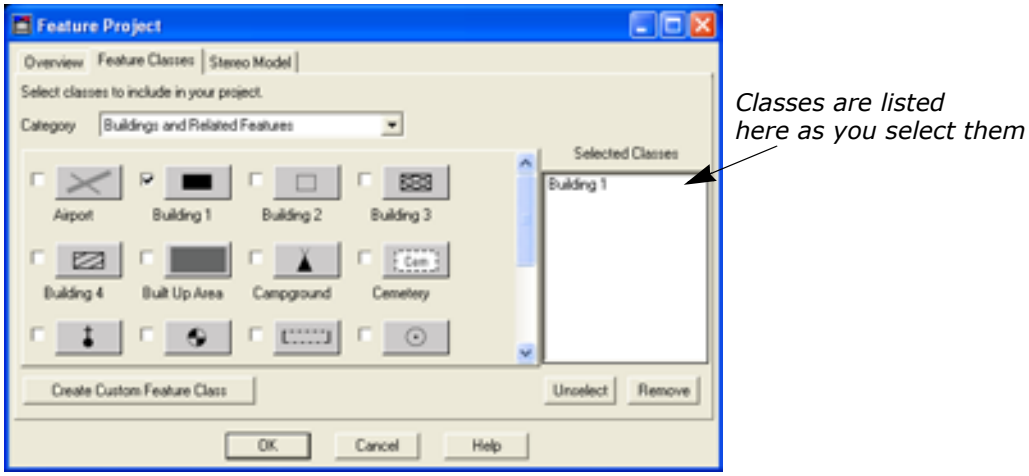
1. Click the **Category** dropdown list and select **Buildings and Related Features**.



2. Use the scroll bar at the right of the features to see all of the different classes included in this category.

3. Scroll back up and click the checkbox next to **Building 1**.

   That feature is added to the **Selected Classes** list.

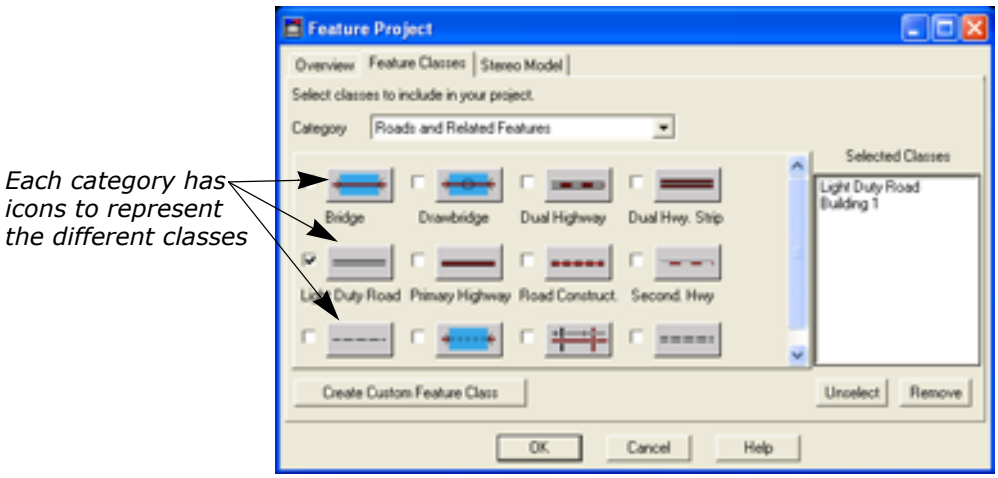


Select Roads and Related Features

1. Click the **Category** dropdown list again and choose **Roads and Related Features**.

2. Click the checkbox next to the **Light Duty Road** feature.

   This feature is also added to the **Selected Classes** list.

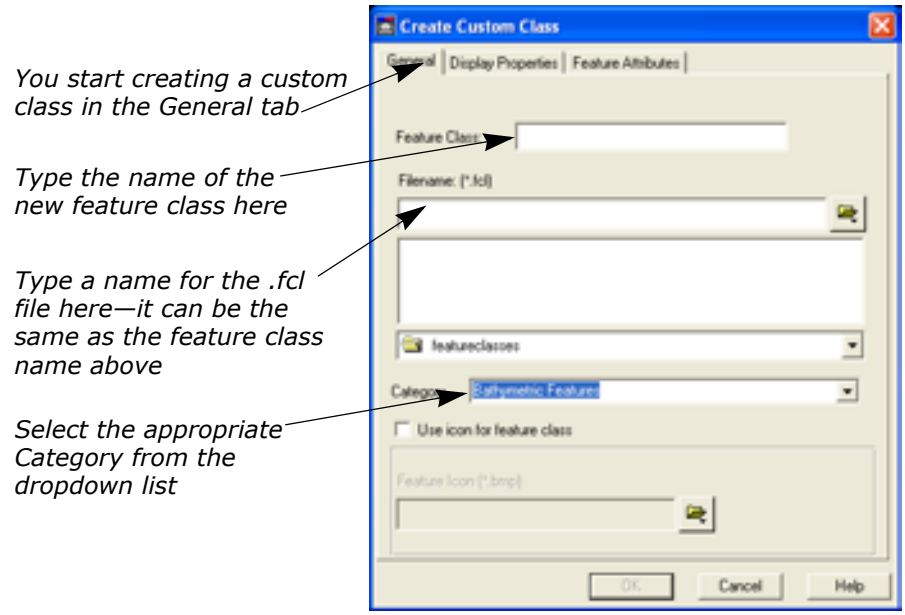


Create a Custom Feature Class

You are also going to be digitizing a sidewalk area in this exercise. Next, you are going to create a custom feature class just for sidewalks.

1. Click the **Create Custom Feature Class** button at the bottom of the **Feature Classes** tab.

   The Create Custom Class dialog opens on the **General** tab.



2. Click in the **Feature Class** window and type **Sidewalk**.

   Next, you need to create the .fcl file. The .fcl file is a feature class file that holds all the information for a given feature category such as the icon associated with it and attribute information.

3. Click in the **Filename** window and type **sidewalk**, then press Enter on your keyboard.

   The .fcl extension is automatically added. Next, you need to select which category you want your new feature associated with.

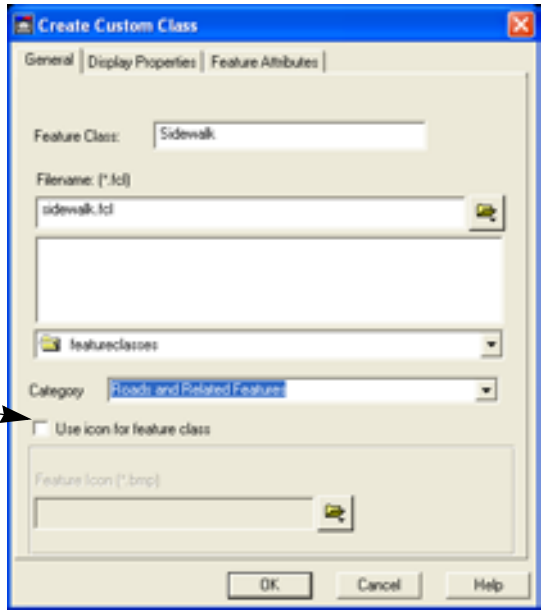
4. Click the **Category** dropdown list and select **Roads and Related Features**.

   If you like, you can even assign an icon to the feature class. To do so, click the **Use icon for feature class** *checkbox, and then select the appropriate .bmp file from the* **Feature Icon** *list.*

   When you are finished, the Create Custom Class dialog looks like the following.

You also have the option to assign an icon to the feature class

Icons are bitmap (.bmp) files*



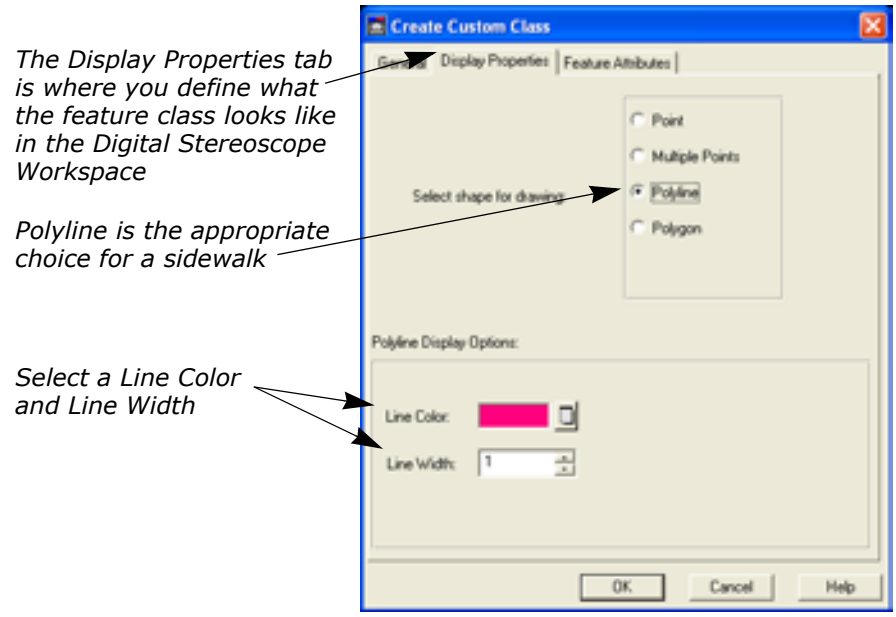
5. Click the **Display Properties** tab of the Create Custom Class dialog.

   Since the feature class is **Sidewalk**, the reasonable shape for drawing is a polyline.

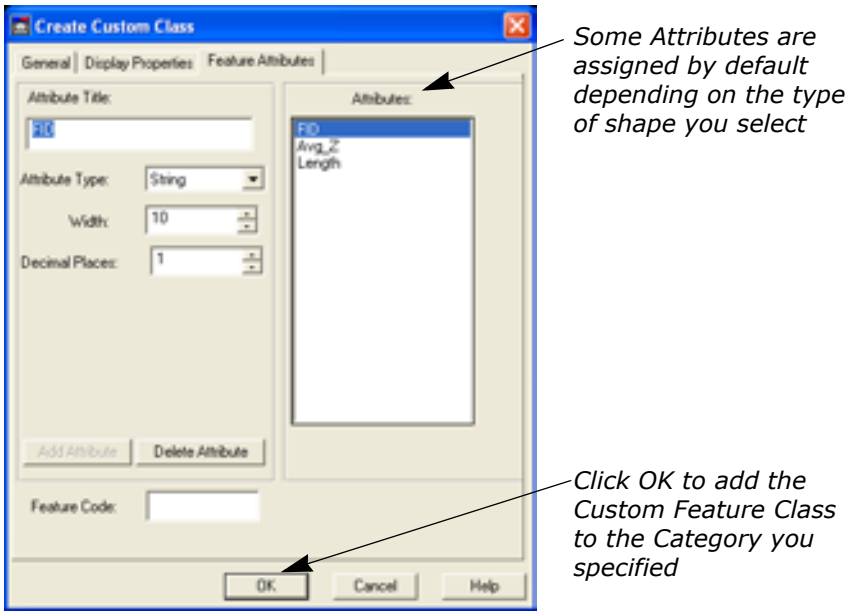
6. In the **Select shape for drawing** section, click to select **Polyline**.

7. If you wish, click the dropdown list to select a different **Line Color**, and enter a different **Line Width**.

   The **Display Properties** tab looks like the following.



8. Click the **Feature Attributes** tab of the Create Custom Class dialog.

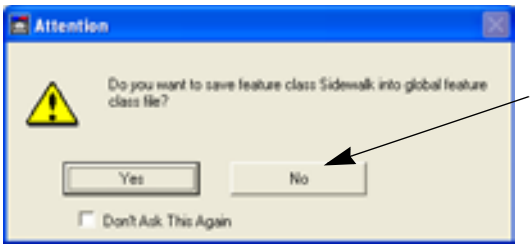


The **Attributes** are automatically selected depending on the type of shape (for drawing) you select for your custom feature. If you wish, you can add additional attributes here.

For information on creating additional attributes, see the On-Line Help.

9. Click **OK** in the Create Custom Class dialog.

The following Attention dialog opens.



10. Click **No** in the Attention dialog.

    By clicking **No**, the **Sidewalk** feature class is included as part of the current project only, and the feature classes originally distributed with Stereo Analyst remain unaltered.

    It is highly recommended that the original feature class files not be edited or modified.

    You are returned to the **Feature Classes** tab. The **Sidewalk** feature class has been added to the **Roads and Related Features** category.

11. Click the checkbox to select the **Sidewalk** feature class.

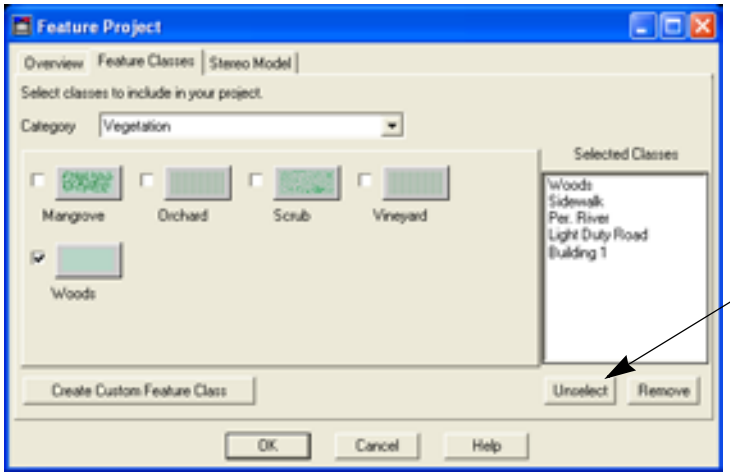
Select Rivers, Lakes, and Canals

1. Click the **Category** dropdown list and select **Rivers, Lakes, And Canals**.
2. Click the checkbox next to the **Per. River** feature class.

Select Vegetation

1. Click the **Category** dropdown list and select **Vegetation**.
2. Click the checkbox next to **Woods**.

   The **Feature Classes** tab now looks like the following, with all the feature classes listed along the right-hand side under **Selected Classes**.

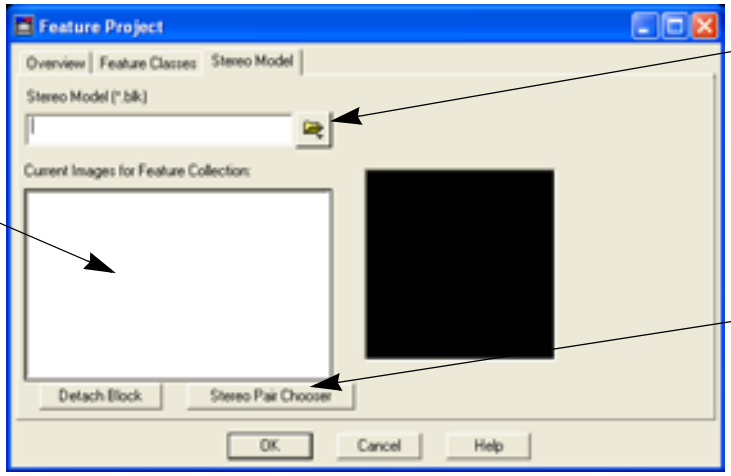


If you decide you do not want to collect a feature of a certain type, select it, then click the Unselect button

Enter Information into the Stereo Model

Now that you have named your project and selected feature classes, you can use the **Stereo Model** tab to select the block file and DSM from which you want to collect features.

1. From the Feature Project dialog, click the **Stereo Model** tab.



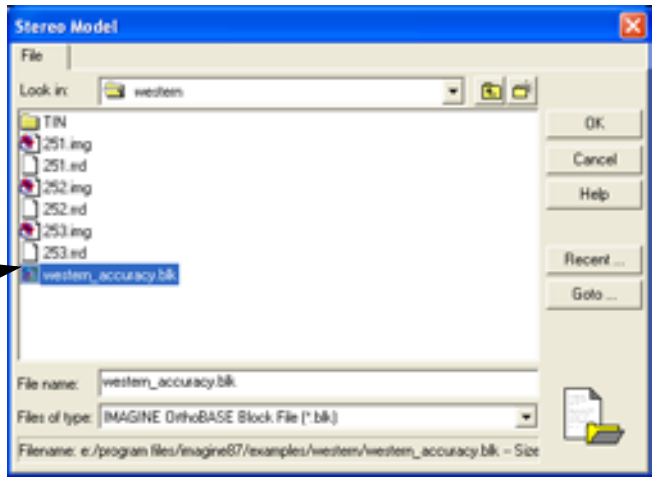
Select the IMAGINE LPS Project Manager block file using this icon

Stereo models in the LPS Project Manager block file display here

You can also access the Stereo Pair Chooser from this tab

2. In the **Stereo Model** tab, click the Open icon .

   The Stereo Model dialog opens.

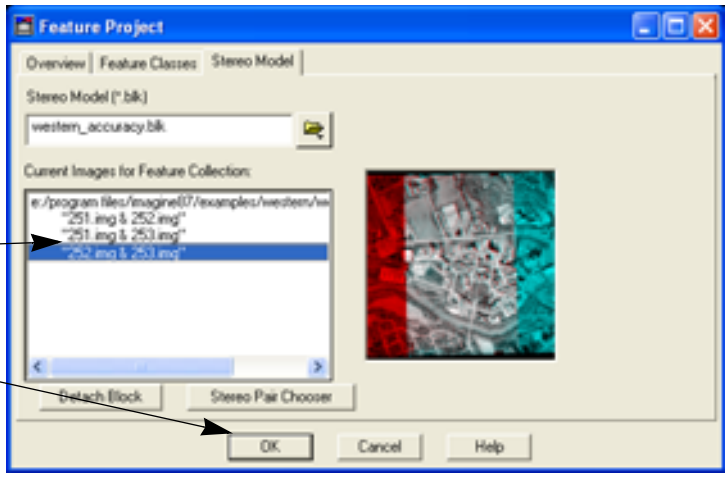


Select the western_accuracy block file

3. Navigate to the <IMAGINE_HOME>\examples\Western directory, and select the file named **western_accuracy.blk**.

4. Click **OK** in the Stereo Model dialog.

   The **Stereo Model** tab is now populated with the information. Now, you can choose a DSM from which to collect features.



This is the DSM from which you collect features

Click OK to load the DSM into the Digital Stereoscope Workspace

5. In the **Current Images for Feature Collection** section of the **Stereo Model** tab, click to select **"252.img & 253.img"**.

   NOTE: If you have not already created pyramid layers for all images in the block file, you are prompted to do so.

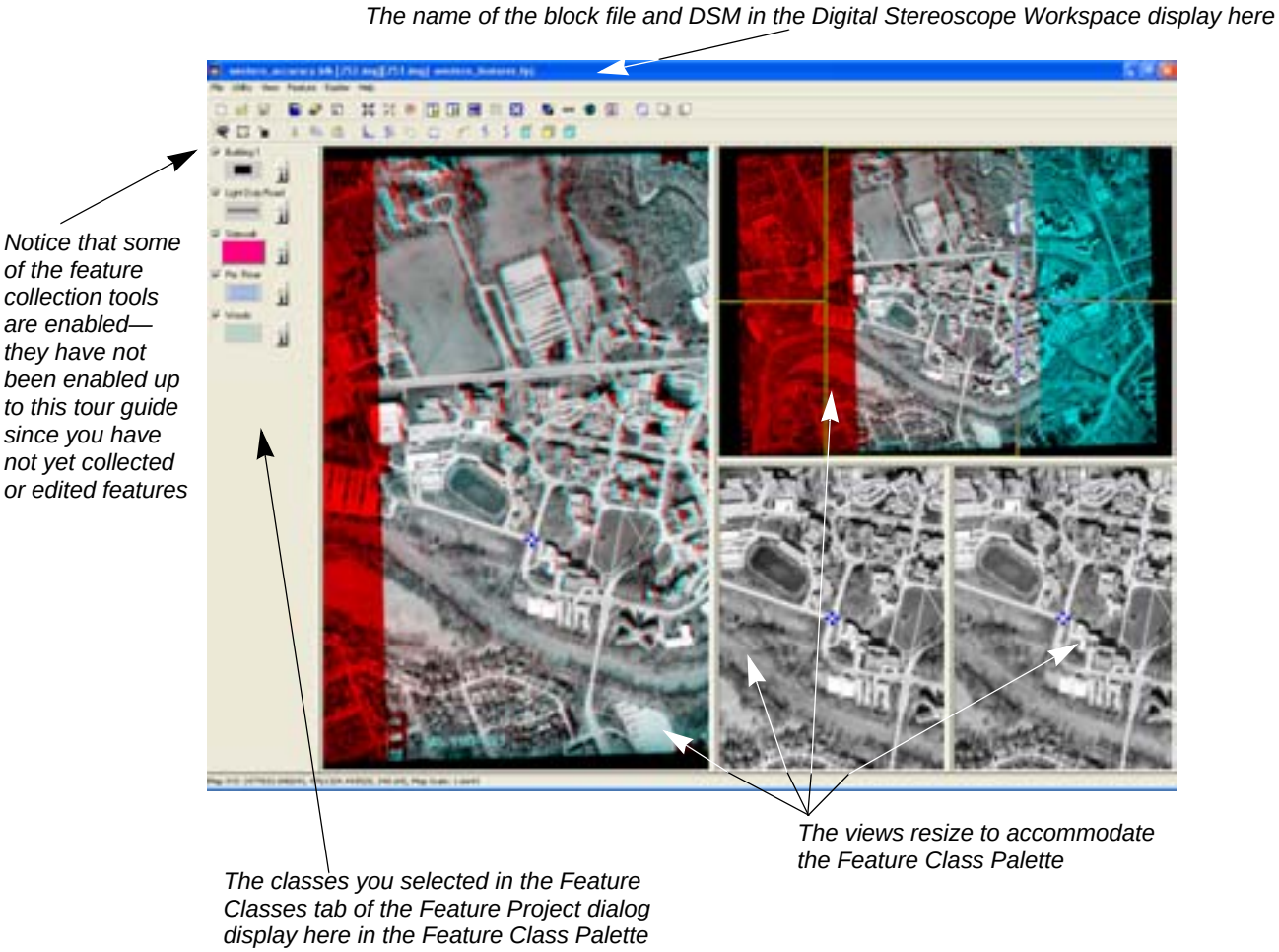
6. If necessary, click **OK** in the dialog to calculate pyramid layers for the image **253.img**.

7. Click **OK** in the Feature Project dialog to transfer all the information to the Digital Stereoscope Workspace.

The DSM is adjusted in the Digital Stereoscope Workspace. You can see that the classes you chose are all neatly arranged in the Feature Class Palette on the left side of the Digital Stereoscope Workspace. You still have access to the same views: the Main View, the OverView, and the Left and Right Views.

8. Adjust the size of the Feature Class Palette and the views to your liking.

For the remainder of the tour guide, you need either red/blue glasses or stereo glasses that work in conjunction with an emitter.



The Feature Class Palette

Once you select feature classes you want to digitize in the DSM, they appear in a column to the left of the Main View.

This area of the Digital Stereoscope Workspace is referred to as the Feature Class Palette. Notice that, to the immediate right of each feature class, there is a icon, which accesses feature properties. By clicking this icon, you can access attribute information for all features of that particular type.

Also notice a icon immediately below the feature properties icon of each feature class. By clicking this icon an attribute table occupies the lower portion of the Digital Stereoscope Workspace. Clicking it again causes the Attribute table to close.

Collect Building Features

Collect the First Building

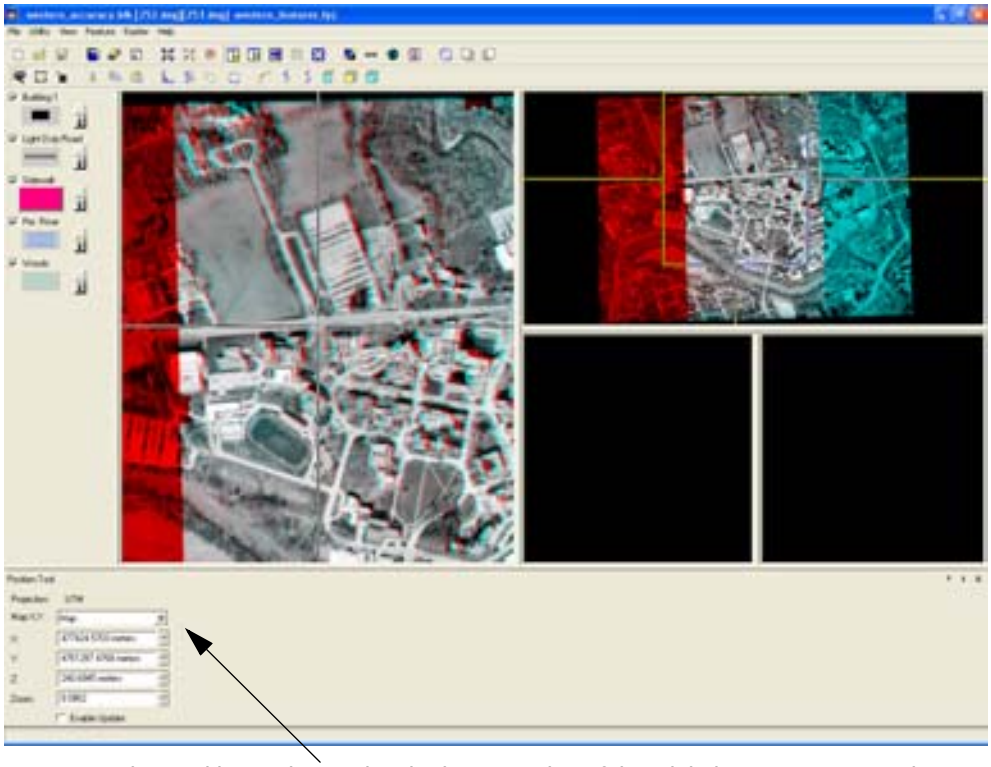
This section shows you how to collect a building, then make the feature 3D by using the 3D Polygon Extend tool.

Open the Position Tool

If you remember from "Checking the Accuracy of a DSM", you can use the Position tool to drive to certain coordinate positions in an image.

1. Click the Position tool icon in the toolbar of the Digital Stereoscope Workspace.

   The Digital Stereoscope Workspace adjusts to accommodate the Position tool.



The Position tool occupies the lower portion of the Digital Stereoscope Workspace

2. In the Position tool, type the value **477609** in the **X** field, then press Enter on your keyboard.
3. Type **4761280** in the **Y** field, then press Enter.
4. Type **263.78** in the **Z** field, then press Enter.

5. Type **0.8** in the **Zoom** field, then press Enter.

   NOTE: The zoom extent is an approximate value, which is recorded to four decimal places.

   The following building displays in the Digital Stereoscope Workspace.

6. Click the Close icon in the Position tool to maximize the display area.
7. Zoom in so that the building fills the Main View.
8. Adjust the x-parallax as necessary.

Select the Building Feature and Digitize

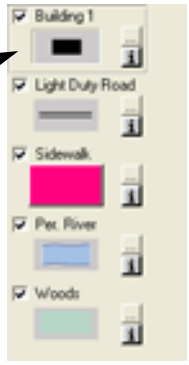
Now that you have located the correct building, you can select the **Building 1** feature class and start digitizing using some of the feature collection tools in Stereo Analyst.

1. From the list of feature classes, click to select the **Building 1** icon

.

   Once you select the feature class, it appears to be depressed and outlined in the Feature Class Palette.

Notice that the Building 1 class has a border around it, which indicates it is active

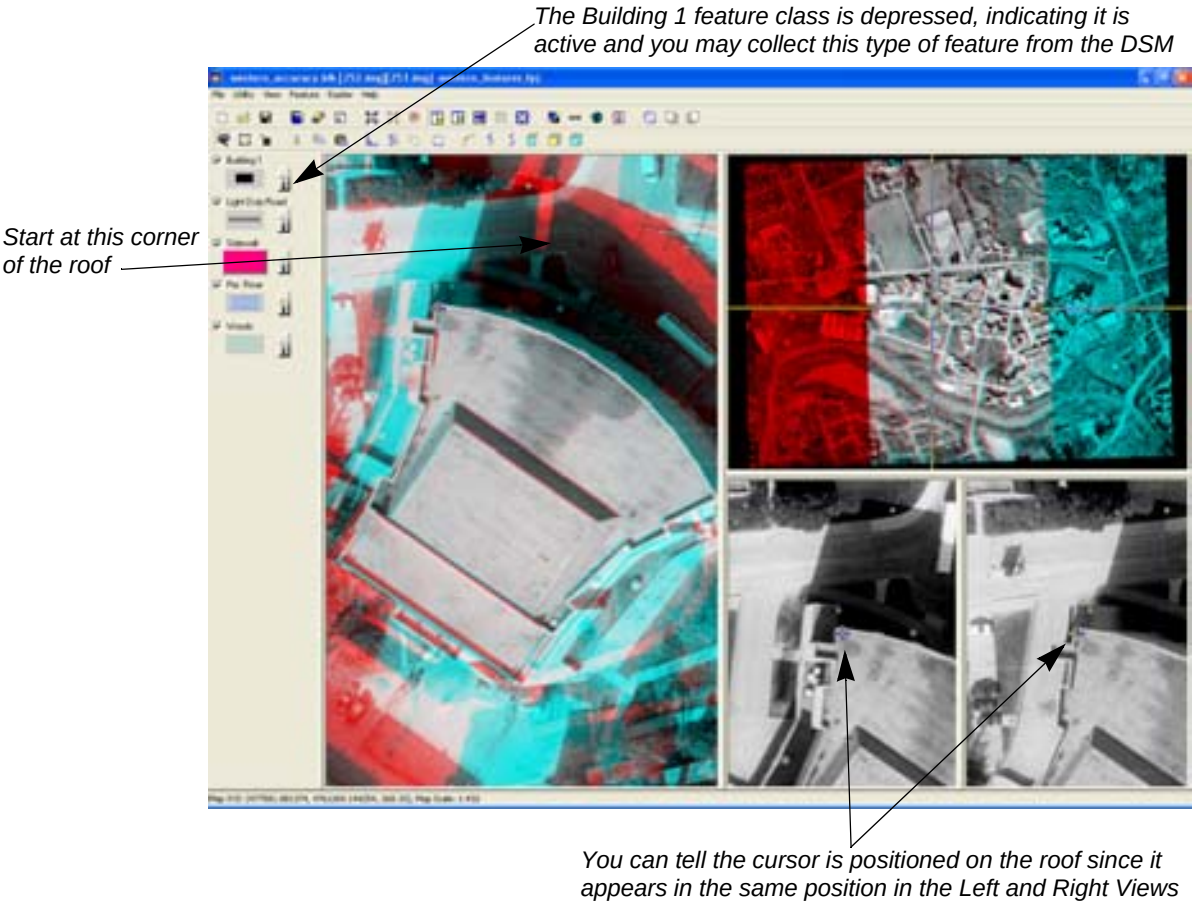


2. Move your mouse into the display area and position the cursor at the northernmost corner of the building.

3. Adjust the cursor elevation by rolling the mouse wheel until it rests on top of the roof of the building.

For more information on adjusting the elevation of the cursor, see "Position the 3D Cursor".

Alternately, you can use the Terrain Following Cursor to ensure that the cursor is always on the feature of interest. To enable the Terrain Following Cursor, select **Utility -> Terrain Following Cursor**.

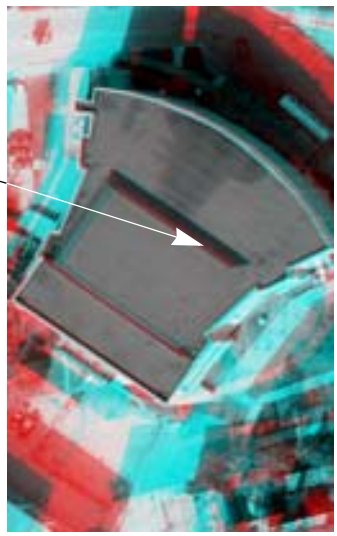


4. Click to collect that corner of the roof, then move the mouse right and continue to digitize along the roof line, adjusting the cursor elevation and x-parallax as necessary.

As you approach the display extent of the Main View, the image automatically pans so that you can continue digitizing. The image area at the edge of the Main View that activates panning is called the auto-panning trigger region. The width of this region can be adjusted by changing the setting for **Auto-Panning Trigger Threshold** *in the Stereo Analyst* **Digitizing Options**. *Other adjustments for panning and roaming can also be made in the Stereo Analyst* **Digitizing Options**.

5. When you have completely digitized the roof of the building, double-click to close the polygon.

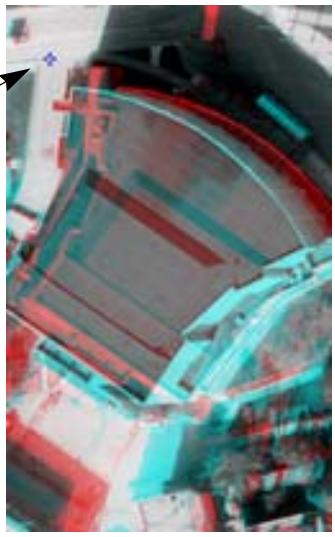
   The filled polygon, which corresponds to the roof of the building, displays in the Main View.



Use the 3D Polygon Extend Tool

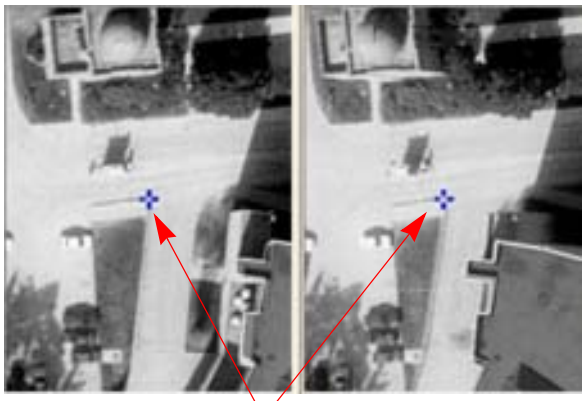
One of the helpful tools provided by Stereo Analyst is the 3D Polygon Extend tool. With it, you can extend polygons, such as the roof you just digitized, to meet the ground. This produces a 3D feature. You can use the 3D Polygon Extend tool on polylines and polygons.

1. In the Main View, position your cursor at a location on the ground close to the building. In this case, we suggest you use the corner of a grassy area close to the first corner you digitized, as depicted in the following illustration.



2. Adjust the x-parallax as necessary.

3. Using the Left and Right Views as a guide, adjust the height of the cursor with the mouse wheel until the cursor rests on the ground.



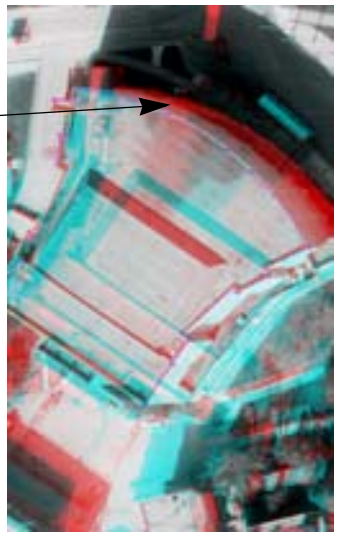
Now that you have positioned the cursor on the ground, you can create a 3D polygon.

4. Click on a line segment of the polygon you created.

NOTE: You can tell the feature is selected because the polygon no longer appears filled and the vertices that create the polygon are highlighted. If you cannot select the polygon, first click the Select icon located on the feature toolbar.

Your building should look like the one pictured in the following illustration.

You can see individual vertices that make up the polygon when the building is selected

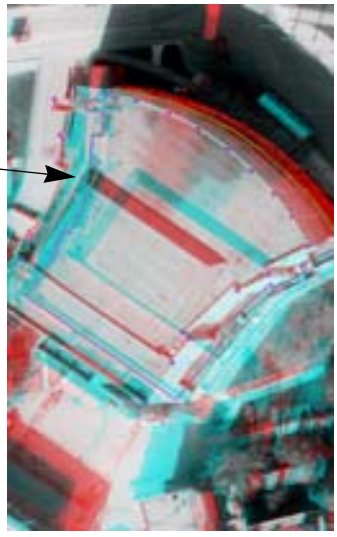


5. Click to select the 3D Polygon Extend tool from the feature toolbar.

6. Click to select any one of the vertices that makes up the roofline.

   Stereo Analyst creates a 3D footprint of the roof which touches the ground. It appears in the Main View as a duplicate of the roof line you digitized, but slightly offset.

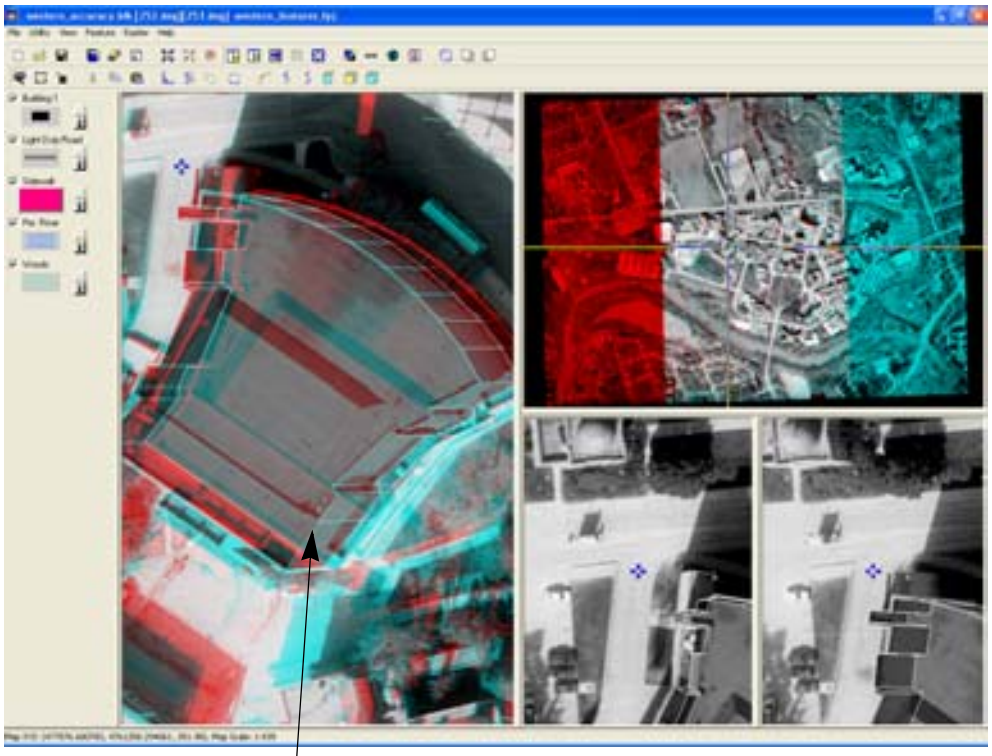
Notice the individual vertices—this indicates that the polygon feature is selected



7. Left-click outside the 3D polygon to deselect it.

   The polygon changes appearance to reflect all of the vertices you digitized to capture the roofline. It now appears as a 3D feature.

8. Zoom in or out until you can comfortably see the 3D polygon in the Main View.



At each vertex location, a line extends to the ground. The polygon is now 3D, and has the added Z, or elevation, component

9. Click the Zoom to Image Resolution icon .

Collect the Second Building

Again, practice using the 3D Polygon Extend tool to create a 3D feature.

Open the Position Tool

1. Click the Position tool icon in the toolbar of the Digital Stereoscope Workspace.

   The Digital Stereoscope Workspace adjusts to accommodate the Position tool.

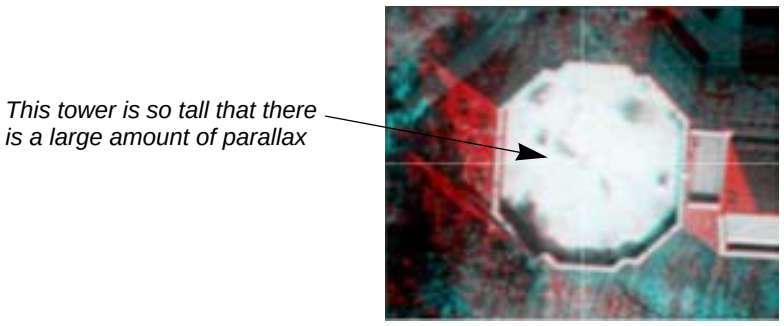
2. In the Position tool, type the value **477966** in the **X** field, then press Enter on your keyboard.
3. Type **4761623** in the **Y** field, then press Enter.
4. Type **264.32** in the **Z** field, then press Enter.
5. Type **3.0** in the **Zoom** field, then press Enter.

   The tower displays in the Digital Stereoscope Workspace.

6. Zoom in so that the tower fills the Main View.

7. Adjust the x-parallax as necessary.

   NOTE: When you collect very tall features, such as this tower, that are surrounded by shorter features, x-parallax is necessarily adjusted for only the feature of interest (that is, the roof). The stereo view of surrounding features and the ground is poor.



8. Click the Close icon in the Position tool to maximize the display area.

Select the Building Feature and Digitize

1. From the Feature Class palette, click to select the **Building 1** icon

.

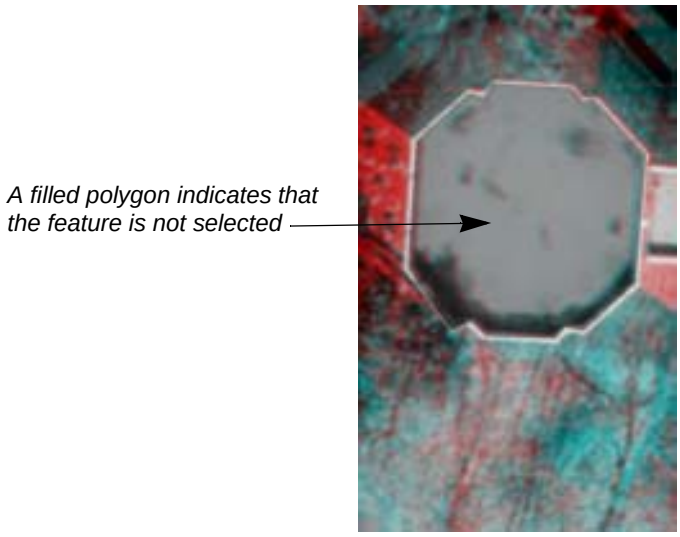
2. Move your mouse into the display area and position the cursor at one of the corners of the tower.

3. Adjust the cursor elevation by rolling the mouse wheel until it rests on top of the roof of the tower.

4. Click to collect that corner of the tower, then move the mouse and continue to digitize along the roof line, adjusting the cursor elevation and x-parallax as necessary.

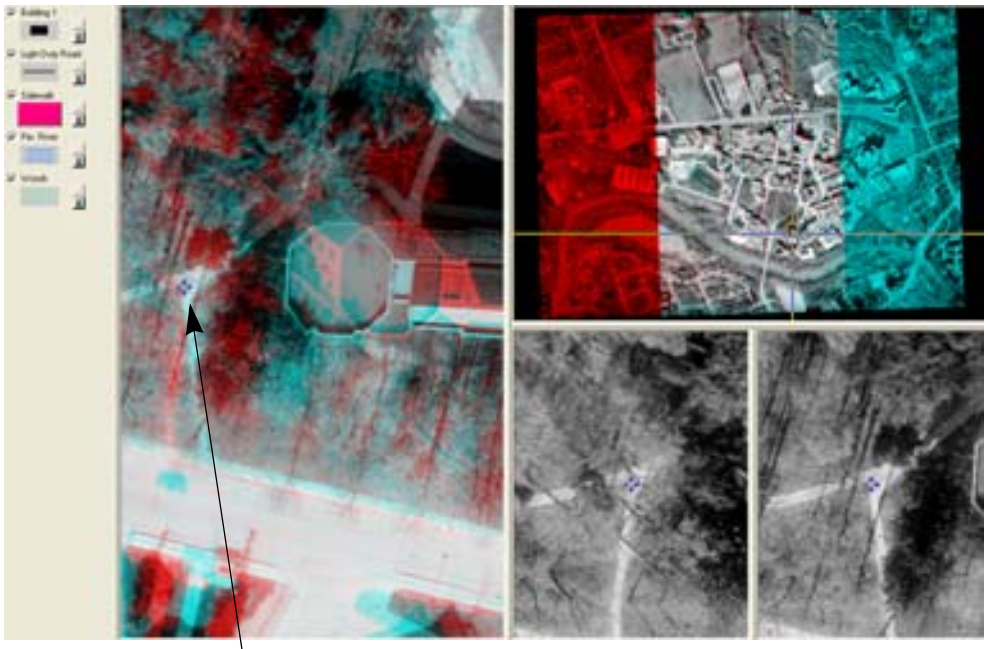
5. When you have completely digitized the roof of the tower, double-click to close the polygon.

   The filled polygon, which corresponds to the roof of the tower, displays in the Main View.



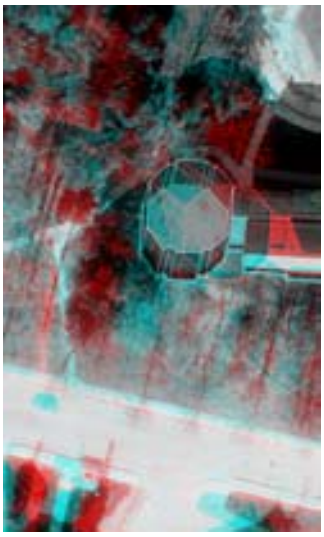
Use the 3D Polygon Extend Tool

1. In the Main View, position your cursor at a location on the ground close to the building. In this case, we suggest you use the corner of a nearby sidewalk.
2. Using the Left and Right Views as a guide, adjust the height of the cursor with the mouse wheel until the cursor rests on the ground.



The elevation of this sidewalk provides information for the 3D Polygon Extend tool

3. Click on a line segment of the polygon you created. Note that the line segments are greatly offset due to x-parallax.
4. Click to select the 3D Polygon Extend tool from the feature toolbar.
5. Click to select any one of the vertices that makes up the roof line.
6. Left-click outside the polygon to deselect it.
   Stereo Analyst creates a 3D feature that touches the ground.



7. Click the Zoom to Full Extent icon .

   You can see the features digitized in the views.

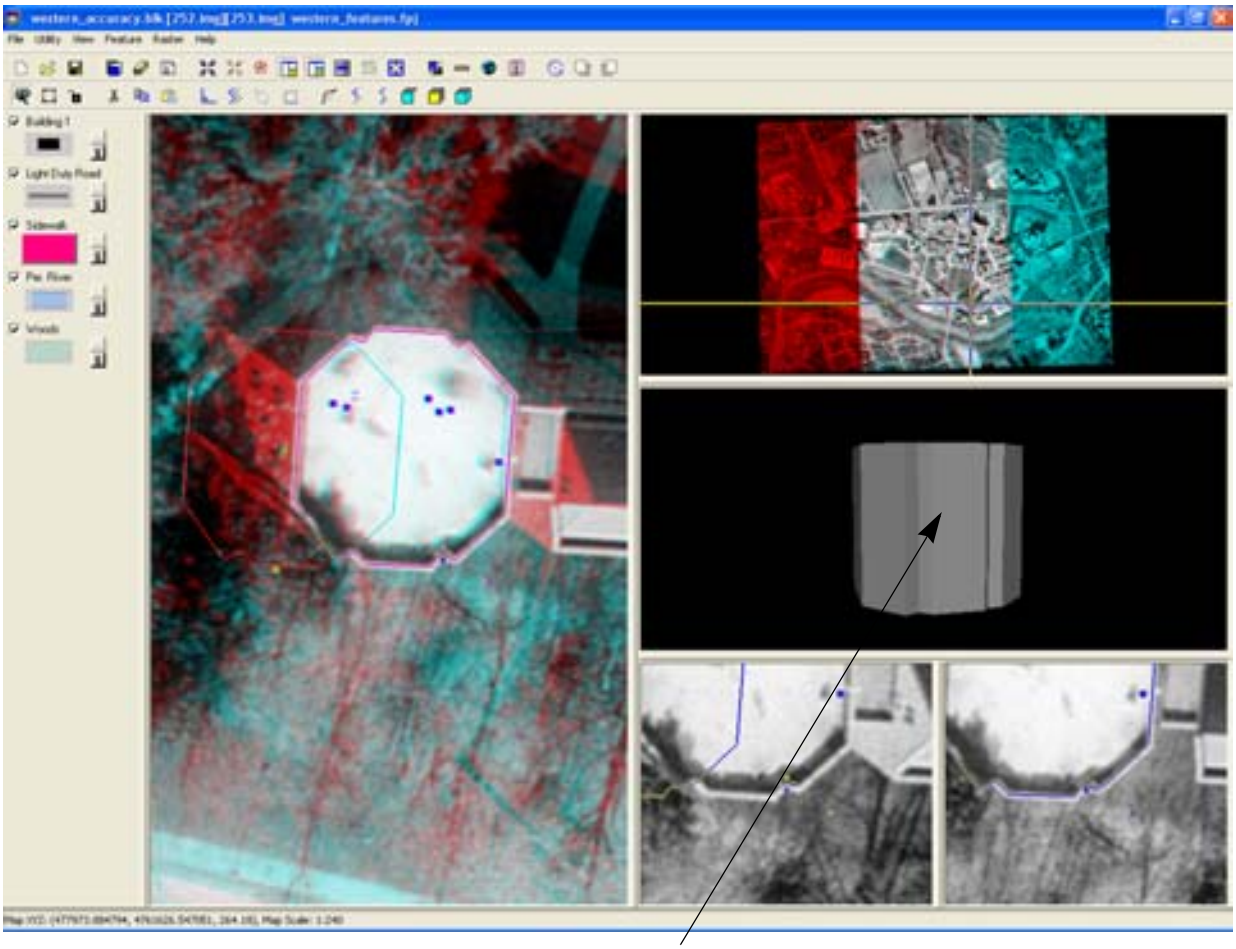
View the Feature in the 3D Feature View

You can view the features you digitize in another view, the 3D Feature View. Like the other views, it has options that can change the display of features. In the 3D Feature View, however, you can manipulate the feature so that you can see all of its sides, top, and bottom.

*You can also export features from the 3D Feature View to formats such as *.wrl (VRML) for use in other applications like IMAGINE VirtualGIS.*

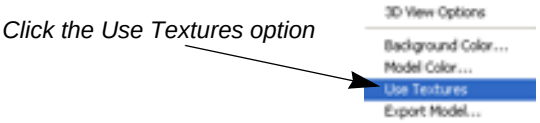
1. Zoom in so that the tower fills the Main View.
2. Click the 3D Feature View icon .
3. Click on one of the line segments of the tower to select it.

   The tower is highlighted and displays in the 3D Feature View.



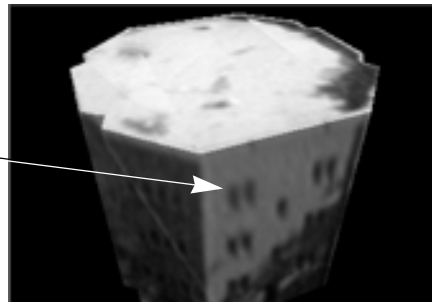
Display features in 3D using the 3D Feature View

4. Right-click in the 3D Feature View to access the **3D View Options** menu.



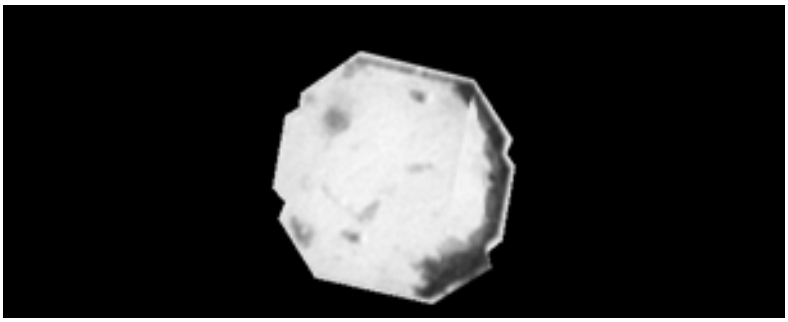
5. Click to select the **Use Textures** option.

   The feature redisplays in the 3D Feature view with the textures, which are real-life attributes of the feature.



6. Practice manipulating the feature in the view by clicking and holding the left or middle mouse buttons, and then moving the mouse in the view.

   In the following illustration, the roof features display.



7. Click the 3D Feature View icon to close the view.

8. Click outside the tower in the Main View to deselect it.

Collect the Third Building

In the last two sections, you practiced collecting 3D buildings using the 3D Polygon Extend tool. In this portion of the tour guide, you are going to use another handy tool: the Orthogonal Snap tool. With it, you can easily create 90° angles.

Open the Position Tool

1. Click the Position tool icon in the toolbar of the Digital Stereoscope Workspace.

   The Digital Stereoscope Workspace adjusts to accommodate the Position tool.

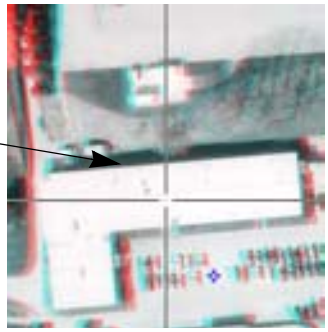
2. In the Position tool, type the value **477623** in the **X** field, then press Enter on your keyboard.

3. Type **4761050** in the **Y** field, then press Enter.

4. Type **245.39** in the **Z** field, then press Enter.

5. Type **0.8** in the **Zoom** field, then press Enter.

   The following building displays in the Digital Stereoscope Workspace. All of its corners are 90° angles.



6. Click the Close icon ✕ in the Position tool to maximize the display area.
7. Adjust the zoom so that the building fills the Main View.
8. Adjust the x-parallax as necessary.

Select the Building Feature and Digitize

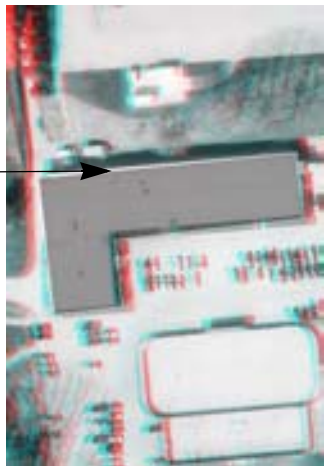
1. From the Feature Class Palette at the left of the Digital Stereoscope Workspace, click to select the **Building 1** icon

.
2. From the feature toolbar, select the Orthogonal Snap tool .

   Once you select the Orthogonal Snap tool, it remains depressed in the feature toolbar, indicating that it is active.
3. Move your mouse into the display area and position the cursor at one of the corners of the building.
4. Adjust the cursor elevation by rolling the mouse wheel until it rests on top of the roof of the building.
5. Click to collect that corner of the building, then move the mouse and continue to digitize along the roof line, adjusting the cursor elevation and x-parallax as necessary.

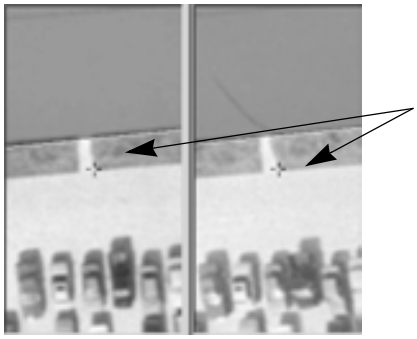
   Notice that, with the second vertex, the cursor is controlled so that you cannot digitize a line that is not 90°. You can, however, add another vertex to the line you digitized to extend it.
6. When you have completely digitized the roof of the building, double-click to close the polygon.

   The filled polygon, which corresponds to the roof of the building, displays in the Main View.



Use the 3D Polygon Extend Tool

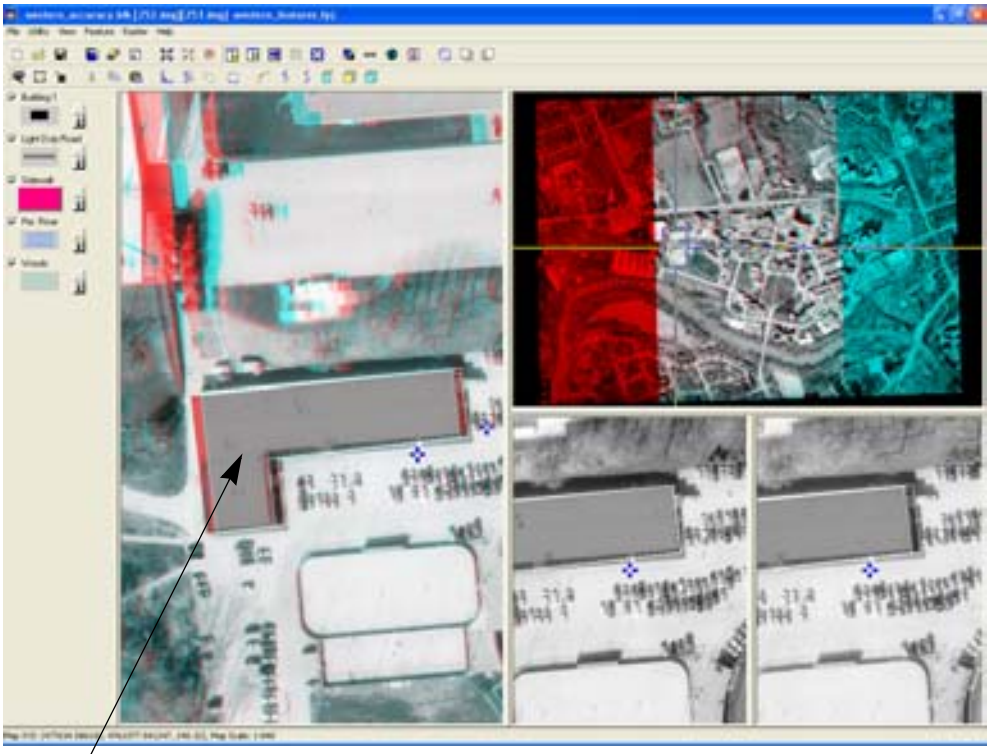
1. In the Main View, position your cursor at a location on the ground close to the building. In this case, we suggest you use the corner of a nearby sidewalk.
2. Zoom in to see the detail of the sidewalk in the Left and Right Views.
3. Adjust the x-parallax as necessary.
4. Using the Left and Right Views as a guide, adjust the height of the cursor with the mouse wheel until the cursor rests on the ground.



5. Click on a line segment of the polygon you created.
6. Click to select the 3D Polygon Extend tool from the feature toolbar.
7. Click to select any one of the vertices that makes up the roof line.
8. Click outside of the building to deselect it.

   Stereo Analyst creates a 3D footprint of the building that touches the ground.

9. Zoom in or out until you can comfortably see the 3D polygon in the Main View.



The 3D building displays in the Digital Stereoscope Workspace Because it is a relatively short building, the 3D effect is not as evident as with a tall building, such as the tower

10. Click the Zoom to Full Extent icon .

Collect Roads and Related Features

Stereo Analyst also provides you with tools with which to collect roads and the like. In this portion of the tour guide, you are going to practice collecting a sidewalk first, then you progress to roads.

Collect a Sidewalk

You can locate the sidewalk to be digitized using the Position tool.

Open the Position Tool

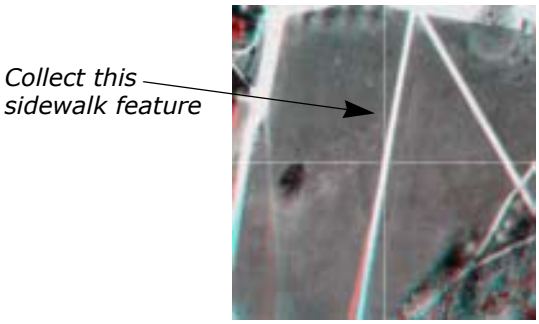
1. Click the Position tool icon in the toolbar of the Digital Stereoscope Workspace.

   The Digital Stereoscope Workspace adjusts to accommodate the Position tool.

2. In the Position tool, type the value **477823** in the **X** field, then press Enter on your keyboard.

3. Type **4761543** in the **Y** field, then press Enter.
4. Type **251.58** in the **Z** field, then press Enter.
5. Type **0.6** in the **Zoom** field, then press Enter.

   The following sidewalk displays in the Digital Stereoscope Workspace.



6. Click the Close icon in the Position tool to maximize the display area.
7. Adjust the zoom and x-parallax as necessary so that the northern portion of the sidewalk is evident in the view.

Select the Sidewalk Feature and Digitize

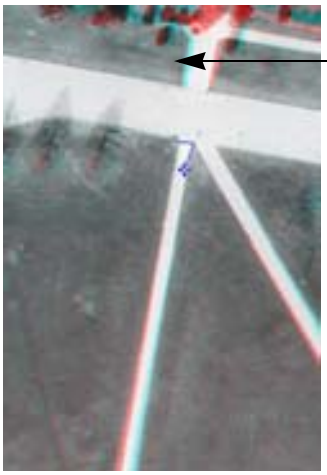
1. From the Feature Class Palette, click to select the **Sidewalk** icon

.
2. From the feature toolbar, select the Parallel Line tool .

   Once you select the Parallel Line tool, it remains depressed in the feature toolbar.
3. Move your mouse into the display area and position the cursor at the northernmost section of the sidewalk.
4. Adjust the cursor elevation by rolling the mouse wheel until it rests on the ground.

   NOTE: You may find this easier if you zoom into the image even more.
5. Click to digitize the first vertex on the left side of the sidewalk.
6. Move your mouse to the right side of the sidewalk.

   At this time, the display looks like the following.



First, you establish the width of the feature you are going to collect by clicking a vertex on either side

7. Click to digitize the first vertex on the right side of the sidewalk.

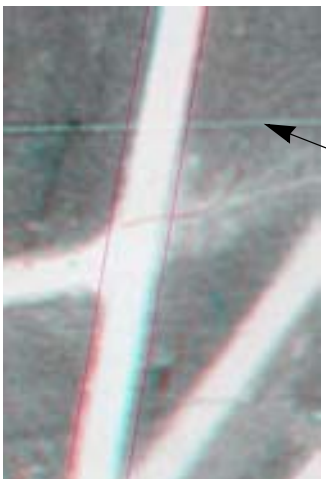
8. Move your mouse back to the left-hand side of the sidewalk, and click to collect the next point.

9. Adjust the cursor elevation as necessary (this sidewalk has a good deal of slope), and continue to collect the sidewalk to the end.

10. Double-click to stop digitizing the sidewalk.

11. Click outside of the sidewalk to deselect it.

The following picture illustrates the termination of the sidewalk, zoomed in.

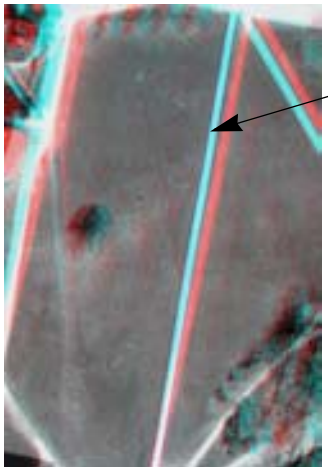


You can see the change in elevation, reflected here as exaggerated x-parallax

Remember, if you make mistakes there are several Stereo Analyst tools to help you correct them, such as the Polyline Extend tool and the Reshape tool. See the On-Line Help for more information.

Zoom Out to See the Entire Feature

1. Use your mouse to zoom out so that the entire sidewalk is visible in the Main View.



You need to adjust x-parallax to see specific portions of the sidewalk in stereo; however, the feature has been collected appropriately

2. Click the Zoom to Full Extent icon .

Collect a Road

Again, locate the appropriate feature using the Position tool.

Open the Position Tool

1. Click the Position tool icon in the toolbar of the Digital Stereoscope Workspace.

   The Digital Stereoscope Workspace adjusts to accommodate the Position tool.

   First, you are going to type coordinates of the point in the road where you will begin digitizing.

2. In the Position tool, type the value **477756** in the **X** field, then press Enter on your keyboard.

3. Type **4761342** in the **Y** field, then press Enter.

4. Type **243.98** in the **Z** field, then press Enter.

5. Type **0.8** in the **Zoom** field, then press Enter.

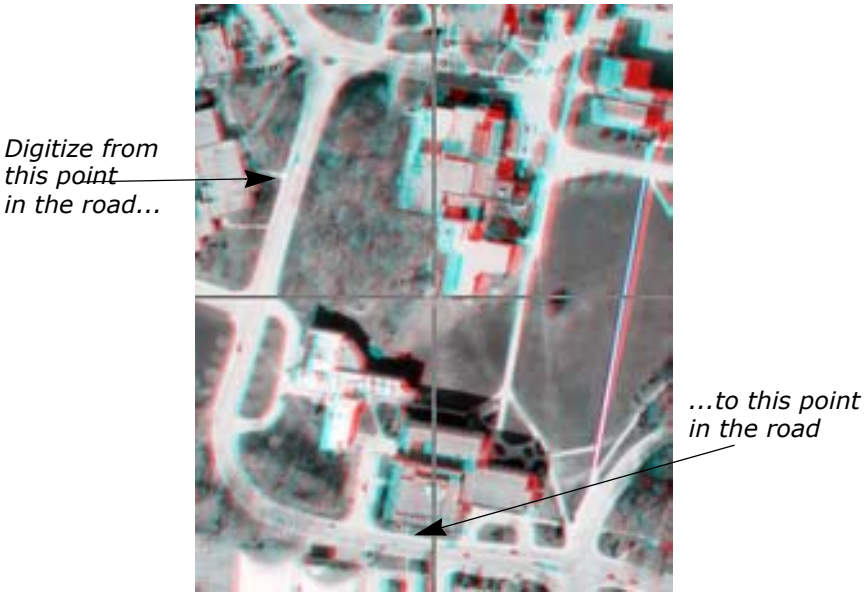
   The point where you begin digitizing displays in the Main View. Now, enter coordinates into the Position tool so you can see where you will finish digitizing the road.

6. In the Position tool, type the value **477968** in the **X** field, then press Enter on your keyboard.

7. Type **4761411** in the **Y** field, then press Enter.

8. Type **238.85** in the **Z** field, then press Enter.

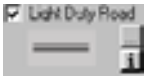
The point where you end digitizing displays in the Main View. The following picture illustrates both the beginning and ending points.



9. Click the Close icon in the Position tool to maximize the display area.

10. Adjust the stereopair in the Main View so that the starting point displays.

Select the Road Feature and Digitize

1. From Feature Class Palette, click to select the **Light Duty Road** icon 

.

2. From the feature toolbar, select the Parallel Line tool .

   Once you select the Parallel Line tool, it remains depressed in the feature toolbar.

3. Move your mouse into the display area and position the cursor at the location where the sidewalk meets the road on the left side.

4. Adjust the cursor elevation by rolling the mouse wheel until it rests on the ground.

   NOTE: You may find this easier if you zoom into the image.

5. Click to digitize the first vertex on the left side of the road.

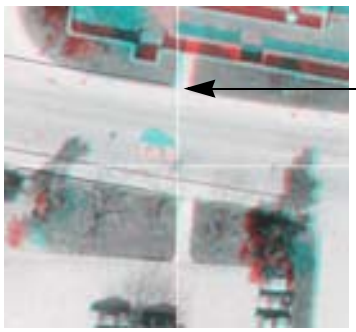
6. Move your mouse across the road, and click to digitize the first vertex on the right side of the road.

7. Move your mouse back to the left side of the road, and click to collect the next vertex.

8. Adjust the cursor elevation as necessary (this road has a good deal of slope), and continue to collect the road to the sidewalk as depicted in the previous illustration.

9. Double-click to stop digitizing the road.

   The following picture illustrates the termination of the road, zoomed in.



Zoom Out to See the Entire Feature

1. Use your mouse to zoom out so that the entire portion of the road you just digitized is visible in the Main View.

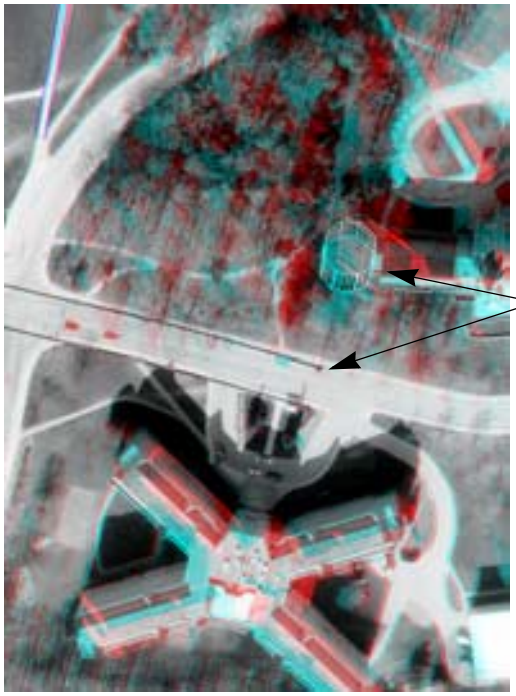
2. Zoom in to and out of the image to see the parallel lines. Note that you need to adjust x-parallax in order to see the digitized points and the road clearly at different elevations.

Extend the Road Feature

When you zoom out to see the area you just digitized, you may decide that you would like to digitize an additional portion of the road. Using the Polyline Extend tool in Stereo Analyst, you can add length to an existing feature.

1. Make sure that the Selector tool is enabled in the Stereo Analyst feature toolbar.
2. Zoom in to see the end of the road.
3. Click to select the end of the road feature you just digitized.

   The vertices at the end of the road are visible.
4. Click the Polyline Extend tool .
5. Click on the last vertex you digitized, and continue collecting vertices along the road.
6. Click to continue to digitize the road. Note that the Parallel Line tool is still active, so the road again has parallel lines.
7. Continue to digitize the road until you come to the tower you digitized in "Collect the Second Building".



The road feature has been extended to the tower you collected earlier in this Tour Guide

8. Double-click to terminate the collection of the road.
9. Click outside the road to deselect it.

10. Click the Zoom to Full Extent icon .

All of the features you have digitized are apparent in the Main View.

Collect a River Feature

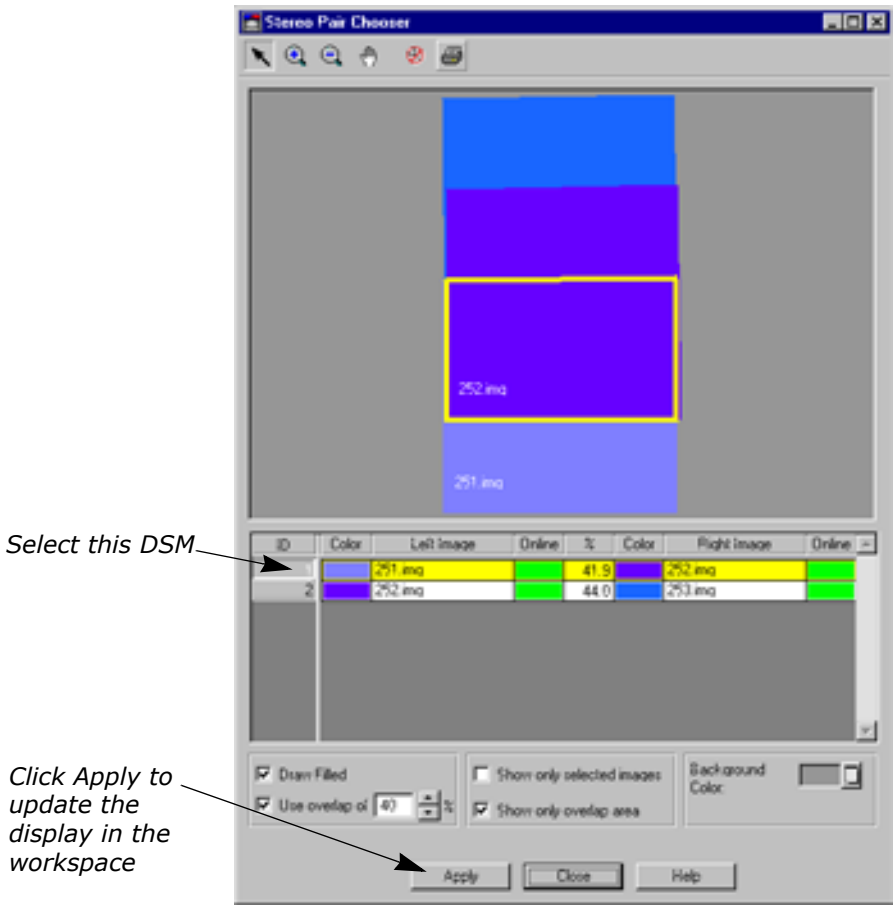
Some features you collect are not linear. Such is the case with the river located in this DSM, you can use stream digitizing to easily collect a feature with irregular contours.

Select a Different Stereo Model

The features you are going to collect are located in a different DSM within the **western_accuracy.blk** file.

1. Click the Stereo Pair Chooser icon .

The Stereo Pair Chooser opens. Here, you can rapidly select another DSM to view in the Digital Stereoscope Workspace.



2. Click in the **ID** column, and select **1**. This corresponds to the DSM consisting of the images **251.img** and **252.img**.
3. Click **Apply,** then **Close**.

   The new DSM displays in the Digital Stereoscope Workspace.

Open the Position Tool

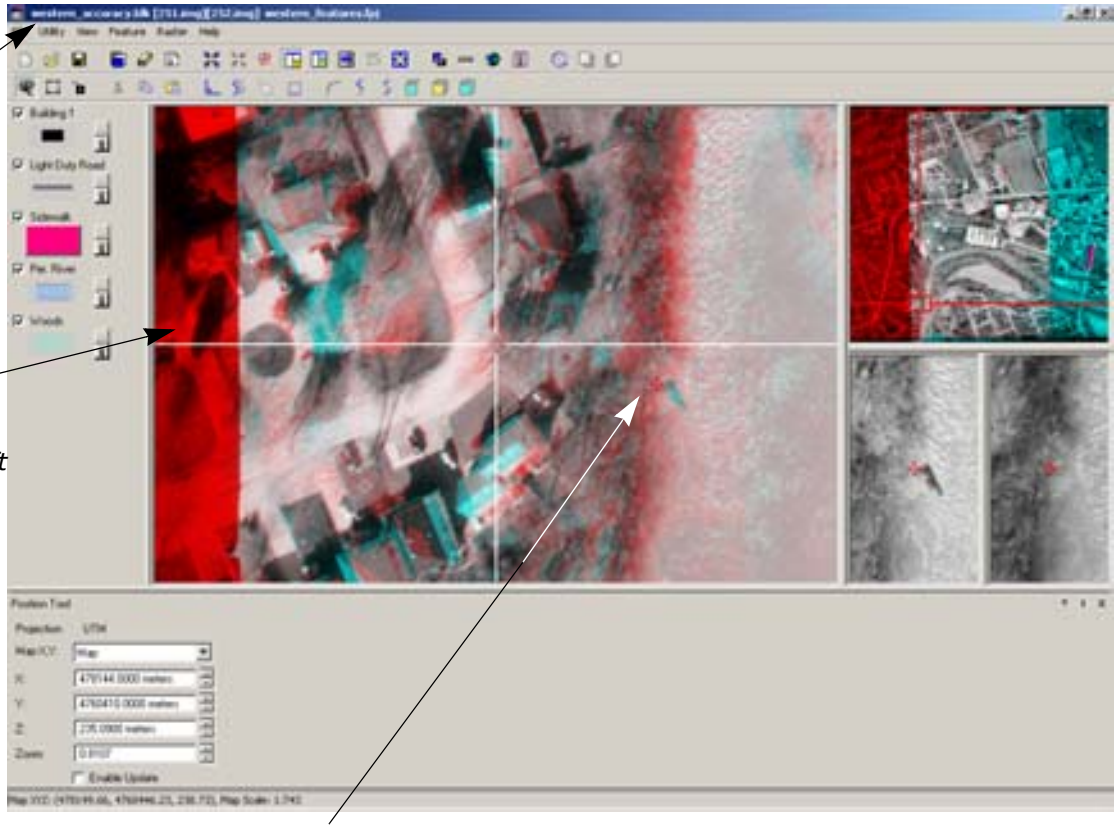
1. Click the Position tool icon in the toolbar of the Digital Stereoscope Workspace.

   The Digital Stereoscope Workspace adjusts to accommodate the Position tool.
2. In the Position tool, type the value **478144** in the **X** field, then press Enter on your keyboard.
3. Type **4760410** in the **Y** field, then press Enter.
4. Type **235.09** in the **Z** field, then press Enter.
5. Type **0.8** in the **Zoom** field, then press Enter.

Stereo Analyst drives to a bend in a road. Just beyond this road is the river bank. You start digitizing the river bank from this point.

6. Click the Close icon to close the Position tool and maximize the display area.

7. Adjust the x-parallax as necessary.



Select the River Feature and Digitize

1. From the Feature Class Palette, click to select the **Per. River** icon

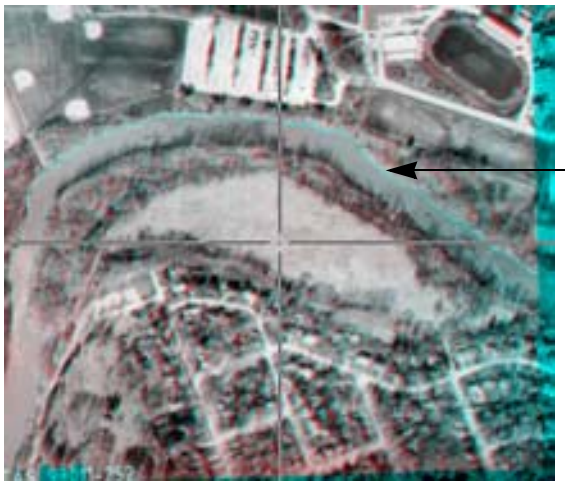
.

2. From the feature toolbar, select the Stream Digitizing tool .

In order for the DSM to readjust its position in the display as you approach the extent of the visible space in the Main View, release the left mouse button. Position the cursor at the extent of the visible area to activate the autopan buffer. Stereo Analyst recognizes when your cursor is in the autopan buffer, and adjusts the stereopair in the view accordingly. You can then continue to use the Stream Digitizing tool.

3. Move your mouse into the display area and position the cursor at the edge of the river.
4. Adjust the cursor elevation by rolling the mouse wheel until it rests on the bank.

   NOTE: You may find this easier if you zoom into the image.
5. Click to digitize the first vertex on the side of the river bordering the subdivision.
6. Hold down the left mouse button and drag the mouse to digitize northward along the river bank.
7. Double-click to terminate collection of the river at the edge of the stereopair.
8. Adjust the display so that you can see the entire river section you digitized.



The river edge feature is highlighted in the Digital Stereoscope Workspace

Collect a Forest Feature

Next, collect a forest feature. You can collect the forest that borders the river.

1. Position the DSM in the Digital Stereoscope Workspace at the origin of the river feature.

2. Click the **Woods** feature in the Feature Class Palette.

3. From the feature toolbar, select the Stream Digitizing tool .

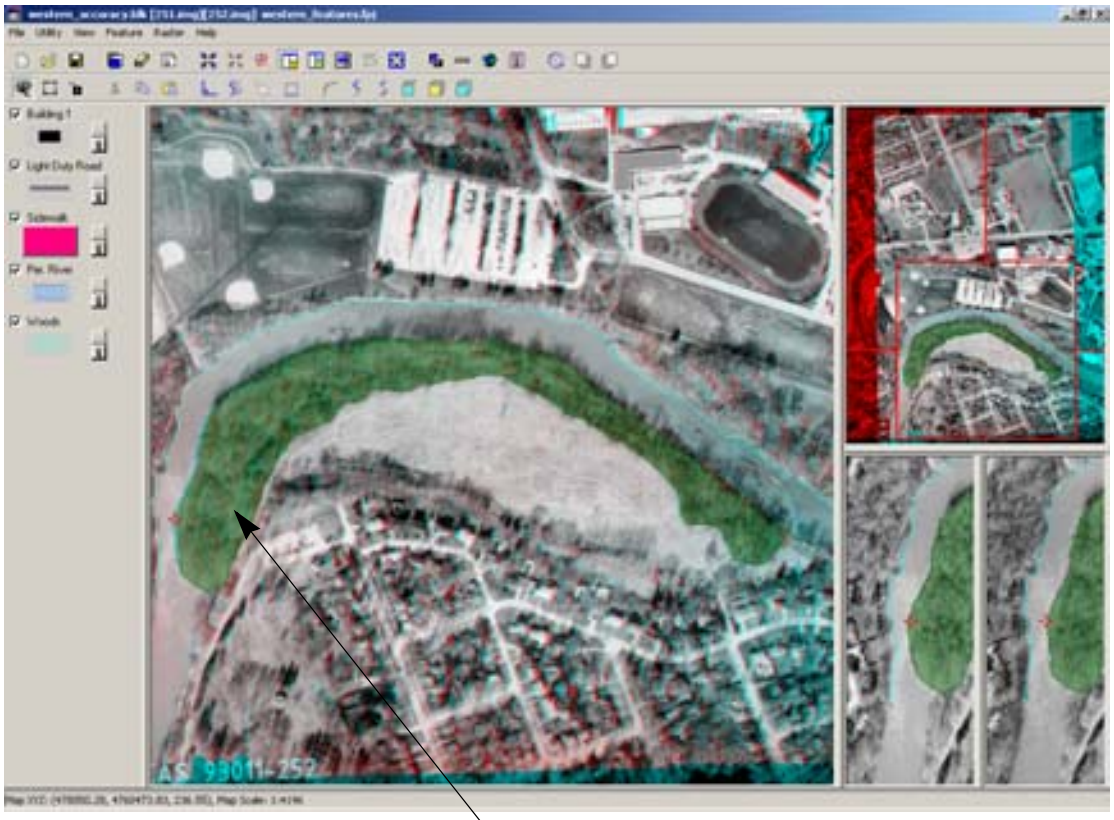
4. Click to collect the first vertex.

5. Hold the left mouse button and drag the 3D floating cursor (adjusting the elevation as necessary) over the forest boundary to trace the feature.

   During the continuous collection of the polyline or polygon feature, vertices are automatically placed over the traced X and Y locations.

6. Double-click to close the forest feature.

7. Zoom out to see the entire feature in the Main View.

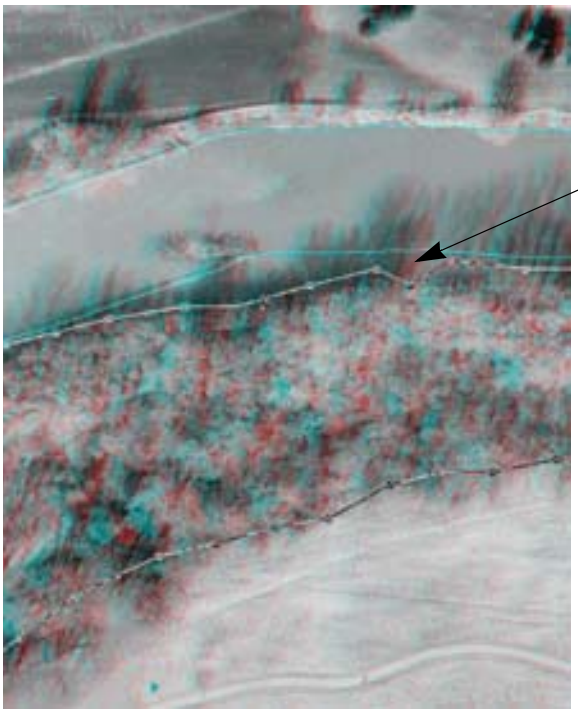


The forest feature displays as a green, filled polygon

Reshape the Feature

You can zoom in and reshape the feature to correct any mistakes you may have made in the stream digitizing process.

1. Adjust the display of the image in the view to see details of the forest boundary.
2. Click to select the forest feature.
3. Click the Reshape icon .
4. Zoom in to see a more detailed portion of the forest.



5. Click, hold, and drag line segments and vertices that make up the forest feature to move them to a new location.
6. Click the Reshape icon again to deselect it.
7. Click outside the forest feature to deselect it.
8. When you are finished, click the Zoom to Full Extent icon .

Collect a Forest Feature and Parking Lot

Next, you can learn how to create features that share boundaries.

Select a Different Stereo Model

The features you are going to collect are located in a different DSM within the **western_accuracy.blk** file.

1. Click the Stereo Pair Chooser icon .

The Stereo Pair Chooser opens. Here, you can rapidly select another DSM to view in the Digital Stereoscope Workspace.

2. Click in the **ID** column, and select **2**. This corresponds to the DSM consisting of the images **252.img** and **253.img**.

3. Click **Apply**, then **Close**.

   The new DSM displays in the Digital Stereoscope Workspace.

Open the Position Tool

1. Click the Position tool icon in the toolbar of the Digital Stereoscope Workspace.

   The Digital Stereoscope Workspace adjusts to accommodate the Position tool.

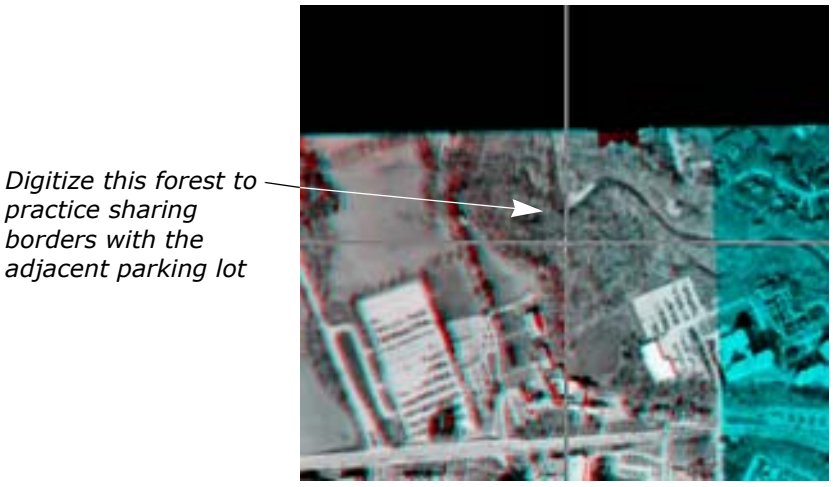
2. In the Position tool, type the value **477052** in the **X** field, then press Enter on your keyboard.

3. Type **4761603** in the **Y** field, then press Enter.

4. Type **242.2148** in the **Z** field, then press Enter.

5. Type **0.1** in the **Zoom** field, then press Enter.

   The following forest displays in the Digital Stereoscope Workspace. It is adjacent to a parking lot, which you are also going to digitize.



6. Click the Close icon in the Position tool to maximize the display area.

7. Adjust the zoom and x-parallax as necessary.

Select the Woods Feature and Digitize

1. From the Feature Class Palette, click to select the **Woods** icon

.

2. From the feature toolbar, select the Stream Digitizing tool .

   Once you select the Stream Digitizing icon, it remains depressed in the feature toolbar, indicating that it is active.

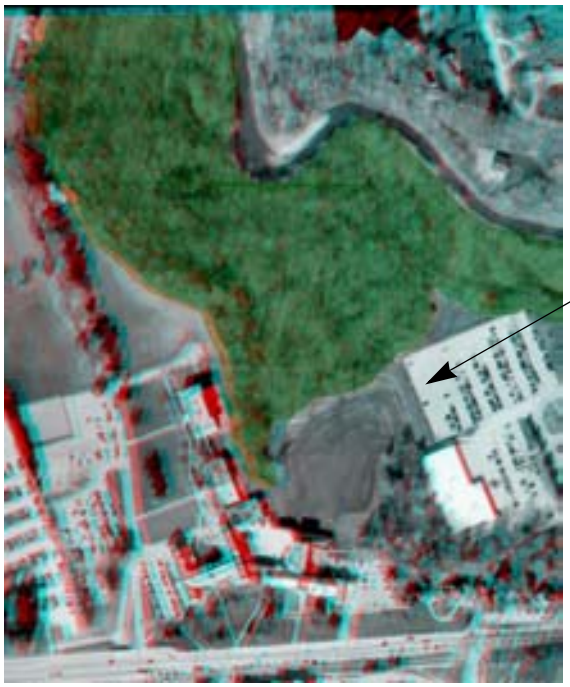
3. Move your mouse into the display area and position the cursor at the southern tip of the forest.

4. Ensure that the cursor is resting on the ground.

5. Left-click, hold, and drag the mouse around the perimeter of the forest to collect it.

6. When you have completely digitized the forest, double-click to close the polygon.

   The filled polygon of the forest feature displays in the Main View.

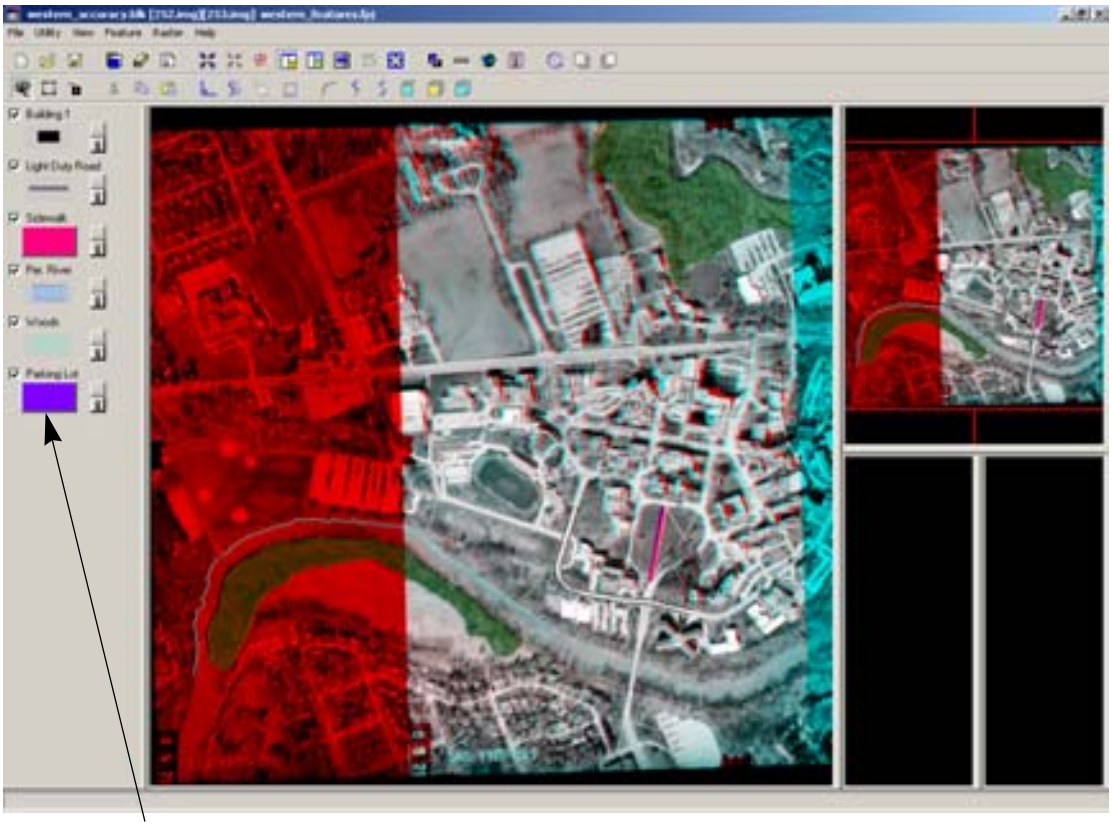


Create and Add a Custom Feature Class to the Palette

There is a parking lot that borders the forest. This feature clearly shares a border with the forest you just digitized. However, there is not a feature class to represent it. You can add feature classes (even a custom feature class) to the Feature Tool Palette at any time. First, create the custom feature class **Parking Lot**, then you can use the Boundary Snap tool to join the parking lot with the forest feature.

1. From the **Feature** menu, select **Feature Project Properties**.
2. Click the **Feature Classes** tab in the Feature Project dialog.
3. Click the **Create Custom Feature Class** button.
4. In the Create Custom Class dialog, type **Parking Lot** in the **Feature Class** field.
5. Type **parkinglot** in the **Filename** field.
6. Click the **Category** dropdown list and choose **Buildings and Related Features**.
7. Click the **Display Properties** tab.
8. Click **Polygon** in the **Select shape for drawing** field.
9. Click **OK** in the Create Custom Class dialog.
10. Click **No** in the dialog asking you if you want to save the new class to the global features.
11. In the Feature Project dialog, click the **Category** dropdown list and select **Buildings and Related Features**.
12. Click the checkbox next to **Parking Lot**, then click **OK** in the Feature Project dialog.

    The **Parking Lot** class displays on the Feature Tool Palette.



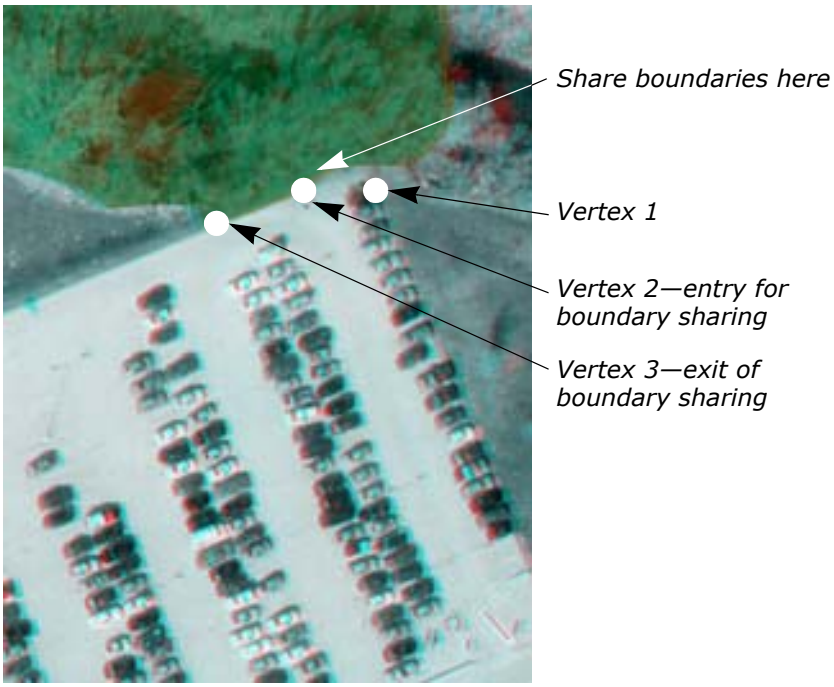
The new feature class is added to the bottom of the Feature Class Palette

Use the Boundary Snap Tool

This forest has a neighboring parking lot with which it shares a boundary. You can use the Boundary Snap tool to connect them.

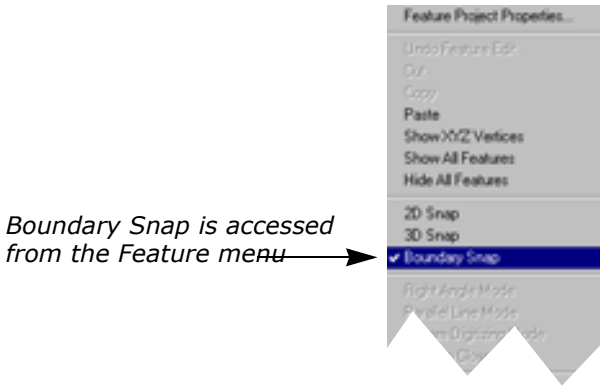
You can only share boundaries with features that are at the same elevation.

1. Zoom to see the parking lot at the southeastern corner of the forest in more detail.
2. Adjust the parallax as necessary to get a clear view of the parking lot.



3. From the **Feature** menu, select Boundary Snap.

   A check mark appears next to the Boundary Snap option.



4. Click to select the **Parking Lot** feature class

.

5. Using the previous picture as a guide, click to select the first vertex of the **Parking Lot** feature at **Vertex 1**. This vertex is not included in the shared boundary.

6. Again, using the picture as a guide, click to place a vertex (**Vertex 2**) on an existing vertex of the forest feature. This is the entry point for boundary sharing

   At this time, Stereo Analyst is recording information about the boundary to be shared.

7. Click to place **Vertex 3** on the farthest (common) vertex of the forest feature. This is the exit point of boundary sharing.

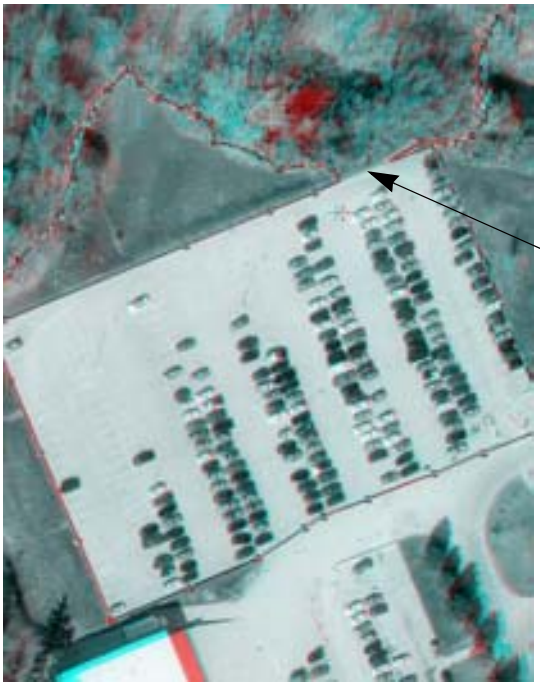
   At this point, you may notice that the digitizing line temporarily disappears. This means that the Boundary Snap tool is sharing the boundaries of the two features.

8. Continue to collect vertices along the perimeter of the parking lot.

9. Double-click to close the perimeter of the parking lot.

10. Hold the Shift key and click to select the boundary of the forest feature, then of the parking lot feature.

    The boundary sharing is evident in the following illustration:



11. Click outside the feature to deselect it.

12. Click the Zoom to Full Extent icon .

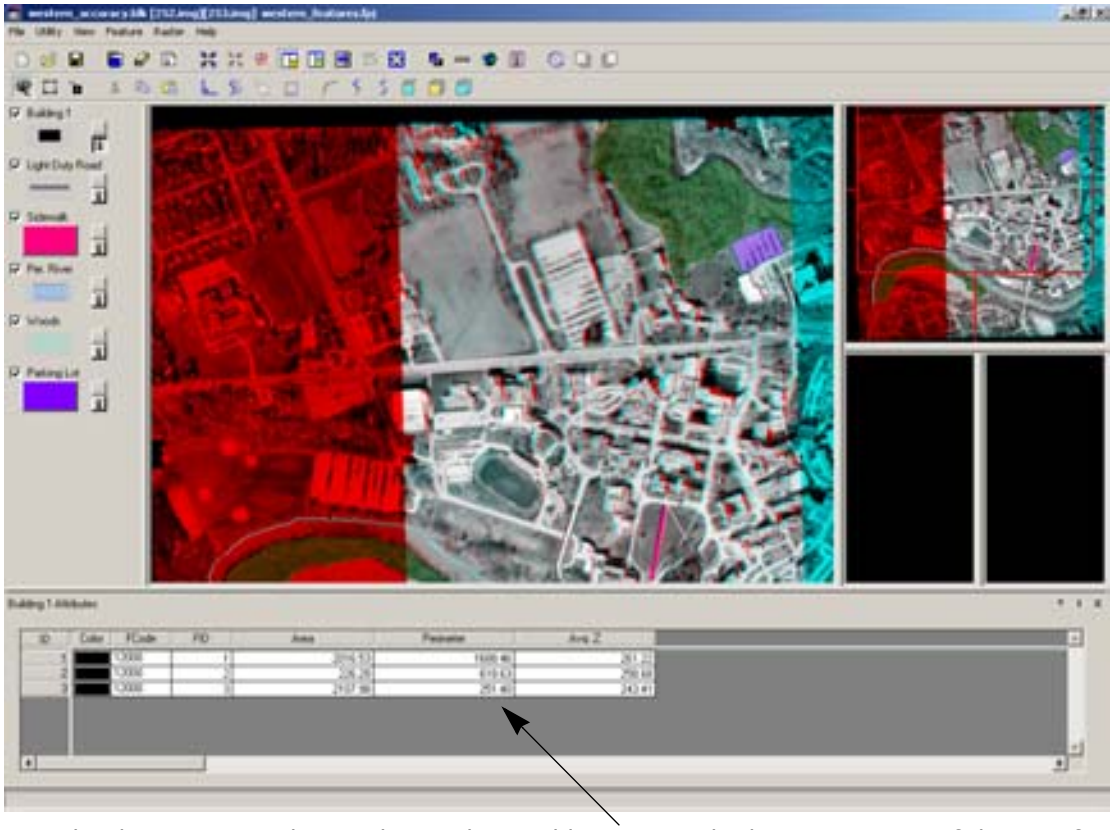
Check Attributes

Now that you have collected a number of features, you can check the attribute tables.

Alternatively, you can open attribute tables for specific features as you digitize. This enables you to input information into attribute fields you specify. For example, the **Building 1** feature class might have an attribute field for an address.

1. Click the Attribute icon next to the **Building 1** feature class.

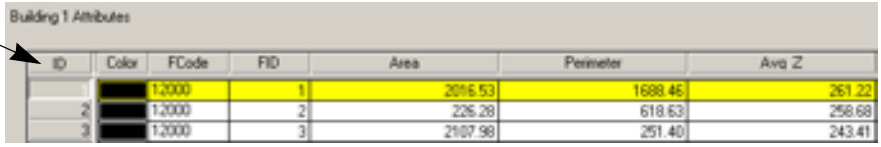
The Digital Stereoscope Workspace adjusts to accommodate the **Building 1 Attributes**.



Like the Stereo Analyst tools, attribute tables occupy the bottom portion of the interface

2. Left-click the **1** column under **ID**.

Click here to select the row



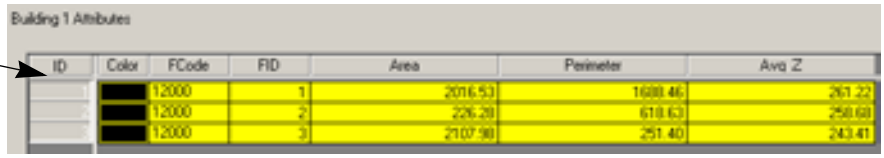
This attribute corresponds to the first building you collected. You may need to zoom in to see it clearly.

Use Selection Criteria

You can use some of the ERDAS IMAGINE tools, such as Selection Criteria, to extract meaningful information from the attribute table.

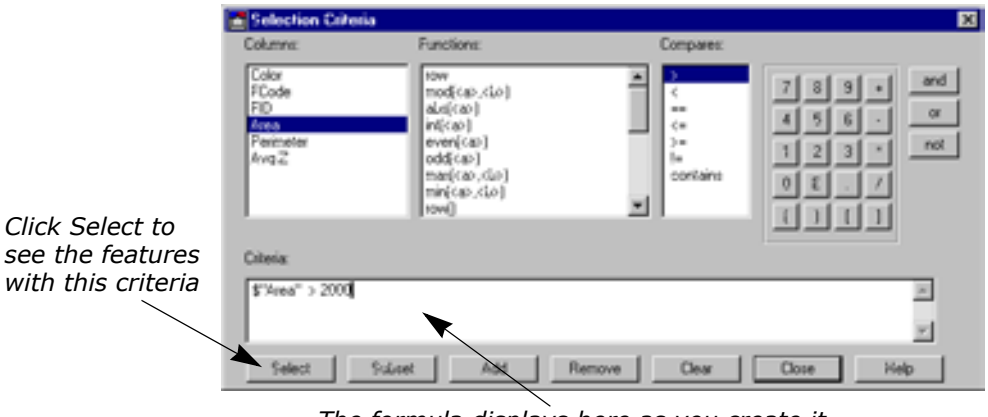
1. Right-click in the **ID** column to open the **Row Selection** menu.
2. Choose **Select All** from the **Row Selection** menu.

   The rows are highlighted in the attribute table:



3. Right-click in the **ID** column and select **Criteria** from the **Row Selection** menu.

   The Selection Criteria dialog opens.

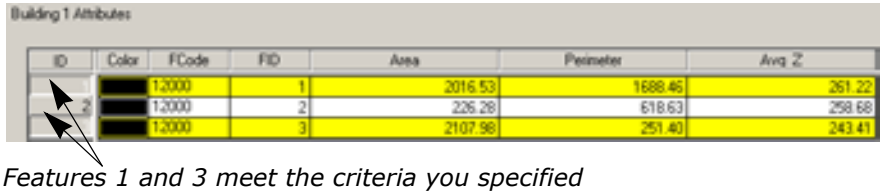


4. In the **Columns** section of the dialog, click **Area**.

5. In the **Compares** section of the dialog, click the greater than sign, **>**.

6. Click **2000** in the number pad, then click **Select** at the bottom of the dialog.

   The features with areas greater than 2000 are highlighted in the attribute table and in the Digital Stereoscope Workspace. Your results may differ from those presented here.



7. Click **Close** in the Selection Criteria dialog.

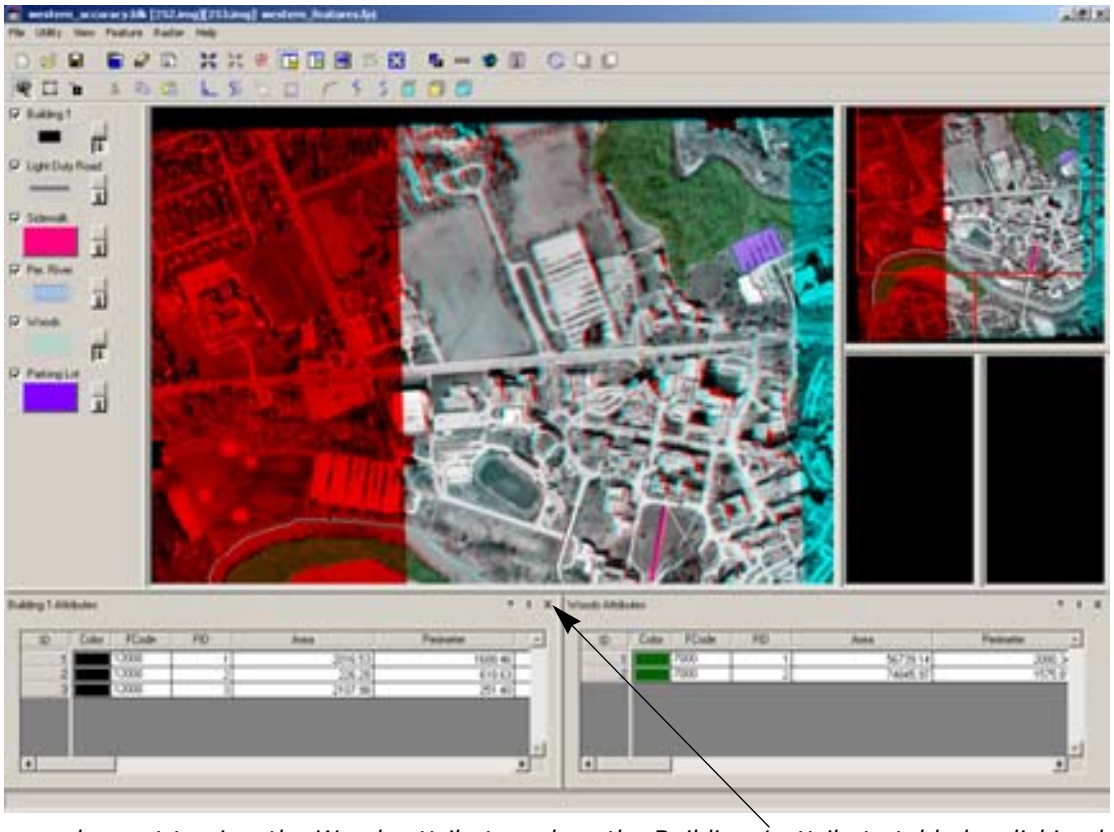
8. Right-click in the **ID** column of the **Building 1** attribute table and click **Select None**.

Check the Woods Attributes

As you continue to open attribute tables associated with your features, the Digital Stereoscope Workspace adjusts to accommodate them. Next, check the attributes of the final feature you collected, the woods bordering the river.

1. Click the Attribute icon next to the **Woods** feature class.

   The attribute table for the woods feature opens.



If you only want to view the Woods attributes, close the Building 1 attribute table by clicking here

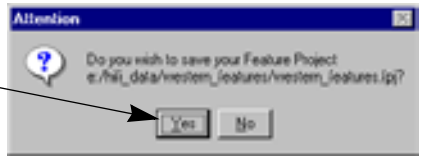
2. Use the scroll bar to see all of the attributes for the **Woods** feature class.

   Like with the **Building 1** feature class, you can also perform analysis on the **Woods** feature class by accessing the **Row Options** and **Column Options** menus. You can even export the data in the attribute tables to a data file (*.dat).

3. Click the Clear View icon .

   The following dialog opens:

Click Yes to save the features you collected



4. Click **Yes** to save your feature project.

If you edit feature class properties in a feature project, the next time you save the project, you are prompted as to whether or not you want to save the display properties and attributes changes to the global feature class. If you select Yes, the global feature class is permanently altered. If you select No, then the display properties and attributes changes are only saved to the feature class in the current project.

It is highly recommended that the original feature class files not be edited or modified.

Next

The next section in this manual is a reference section. In it, you can find helpful information about installation and configuration, feature collection, ASCII files, and STP files. A glossary and list of references are also included for further study.

Texturizing 3D Models

Introduction

Once you have collected your 3D GIS data, you may want to add textures to your models making them as realistic as possible. Attaching realistic textures to your 3D models is as simple as obtaining digital imagery of the building or landmark and mapping that imagery to the model using the Texel Mapper program supplied with Stereo Analyst.

This tour will lead you through the steps involved in accurately and realistically mapping images taken from ground level of the landmark with a digital camera onto the 3D model like the ones you collected in the previous tour.

Getting Started

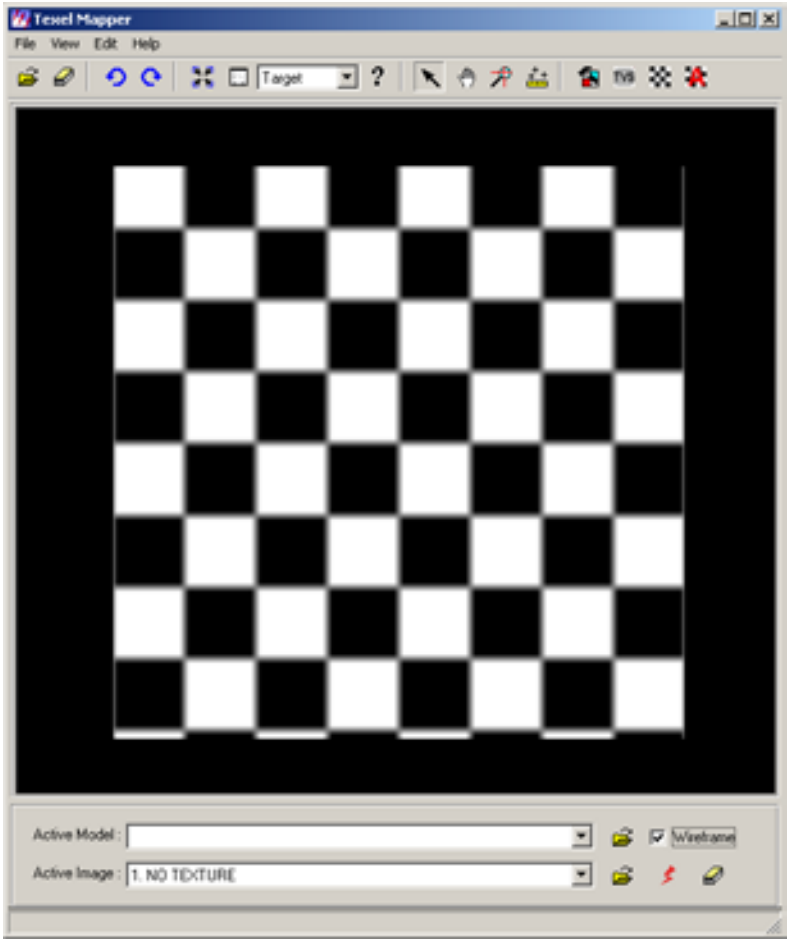
First, you must launch the Texel Mapper program. From the Stereo Analyst menu, select Texel Mapper.

Click here to launch the Texel Mapper

The Texel Mapper opens.

Explore the Interface

Take a few moments to explore the interface.



Loading the Data Sets

Loading the 3D Model

First, we must load a 3D model similar to those we collected in Stereo Analyst.

1. Click the Open button next to the **Active Model** dropdown list.

   A File Selector opens.

2. Navigate to the <IMAGINE_HOME>/examples directory.
3. Select **Multigen-OpenFlight** from the **Files of Type** dropdown list.
4. Select **karolinerplatz.flt** from the list of files and click **OK**.

   The building displays in the Texel Mapper workspace.

In Target mode, dragging allows you to rotate the model in the X and Y directions, while middle-dragging lets you zoom towards and away from the selected model.

Loading the Textures

The textures used in this tour are pictures of the actual building that have been taken with a digital camera.

1. Click the Open button next to the **Active Image** dropdown list.

   A File Selector opens.

2. Navigate to the <IMAGINE_HOME>/examples directory.
3. Select **JFIF (.jpg)** from the **Files of type** dropdown list.
4. Ctrl-click **karolinenplatz_front.jpg**, **karolinenplatz_left.jpg**, and **karolinenplatz_right.jpg** to select them.
5. Click the **Options** tab.
6. Set the band combination to **Red: 1**, **Green: 2**, and **Blue: 3**.
7. Check the **No Stretch** checkbox.
8. Click **OK**.

   All three images are loaded in the background of the Texel Mapper workspace.

Texturizing the Model

You are now ready to texturize the model. There are numerous ways to map textures onto the faces of the model, and the method you choose will depend upon the orientation of the feature of interest in your imagery.

Texturize a Face In Affine Map Mode

The first method of texturization that we will use is called the Affine Map Mode. This mode will directly map a portion of the image onto the model. It works best with head-on photographs that have little or no perspective distortion.

You may want to maximize the Texel Mapper window on your screen so that you have a lot of workspace in which to manipulate the model and images.

1. In the Active Image popup list, select **karolinenplatz_front**.

   The karolinenplatz_front.jpg image displays behind the model.

2. Click and drag the cursor in the workspace to rotate the model so that the front of the model displays.

3. Click the Affine Mapping button to enter Affine Map Options mode.

   The Affine Map Options dialog displays.

4. Right-click on the front face of the model to select one of the polygons.

5. Ctrl-right-click on the other half of the face to select the entire front polygon.

   The selected face of the model is now tiled with a texture, and the vertices of the selected faces have yellow lines that extend off of the viewable area of the workspace.

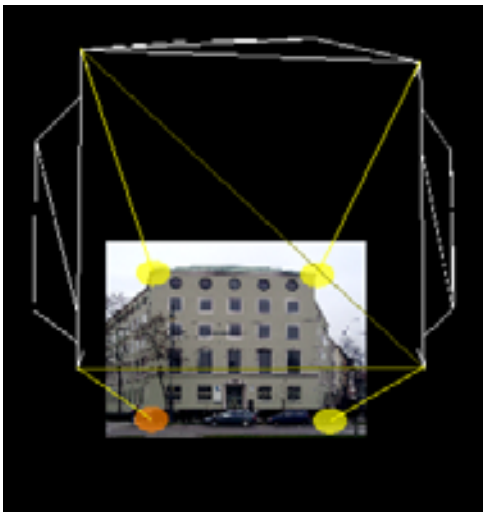
6. Click the **Fit Points to Screen** button on the **Affine Map Options** dialog.

   The image is resized so that all four vertices are fit inside the viewable Workspace.

7. Check the **Wireframe** checkbox.

   The model displays without any textures. Now you can see those portions of the image that were blocked by the model.

8. Drag each of the yellow vertices so that they roughly overlay the corresponding parts of the Active Image.



Do not worry about being precise here, just roughly estimate the positions on the image. We will enlarge the image and fine-tune our vertices in a moment.

9. Click the Fit Points to Screen button to resize the view within the workspace.

10. To zoom in on the Active Image, select the Image Options mode by clicking the button on the Texel Mapper toolbar.

11. Hold the middle mouse button and drag to zoom in. Hold the Left mouse button and drag to pan through the image.

When fine tuning your vertices, it is a good idea to maximize the Texel Mapper display and to zoom in as far as possible on the Active Image. This allows you to be more accurate when adjusting the positions of the vertices.

12. Click the Affine Map Options button to return to the Affine Map mode.

13. Middle-drag to zoom in on the model. It should be large enough to see the effects of moving the vertices, and small enough that it does not block your view of any of the corners of the building in the image.

14. Uncheck the Wireframe button so you can see the texture as it is mapped on the model.

15. Drag the vertices so that they accurately rest on the corresponding building corners in the image.

    As you move the vertices, the texture on the model will warp and stretch. This is particularly evident along the diagonal that joins the two selected polygons.

16. Fine tune the position of each vertex to eliminate any warping or stretching.

    NOTE: Sometimes the corner of a Feature of interest will be occluded in the Active Image, as is the case of the bottom right vertex in this model. You must estimate where that corner lies.

17. Right-click outside of the model to deselect the faces. The front face of the model is textured.

18. Save the model by selecting **File -> Save As -> Multigen OpenFlight Database...** from the Texel Mapper menu bar.

19. Enter **texel_mapper_tour.flt** in the **Save As...** dialog and click **OK**.

Texturize a Perspective-Distorted Face

It is the nature of photography that the sides of features may be distorted due to perspective. That is, objects or vertices that are further away from the camera lens may appear smaller than those that are closer to the camera lens.

If we were to simply use the affine map mode to map a perspective-distorted texture directly onto the model, we would end up with a very warped and stretched texture, rather than an accurate depiction of the model.

You can compensate for these perspective distortions while texturizing a model by adjusting the position of the model so that it mimics as closely as possible the position, Field of View (FOV), and perspective of the feature in the 2D image.

1. Select **karolinerplatz_right** from the **Active Image** dropdown list.

   You can see that this is an example of a perspective-distorted image. The far corner of the building seems smaller that the near corner.

2. Check the **Wireframe** checkbox so you can see the image through the model.

Adjust the Active Image

1. To zoom in on the Active Image, select the Image Options mode by clicking the button on the Texel Mapper toolbar.

2. Hold the middle mouse button and drag to zoom in. Hold the Left mouse button and drag to pan through the image.

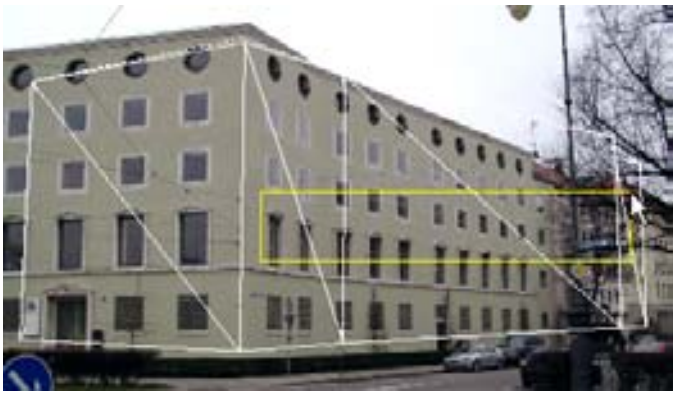
   Display as much of the left side of the building as possible. It is important that you are still able to see all of the vertices in the picture.

Select the Faces

1. Enter the Model Options mode by clicking the button on the Texel Mapper toolbar.

2. Drag the cursor so that the left side of the model is entirely visible in the workspace.

3. Right-hold and drag a selection box that intersects all of the polygons on the right side of the model.



   All of these polygons are highlighted in the workspace.

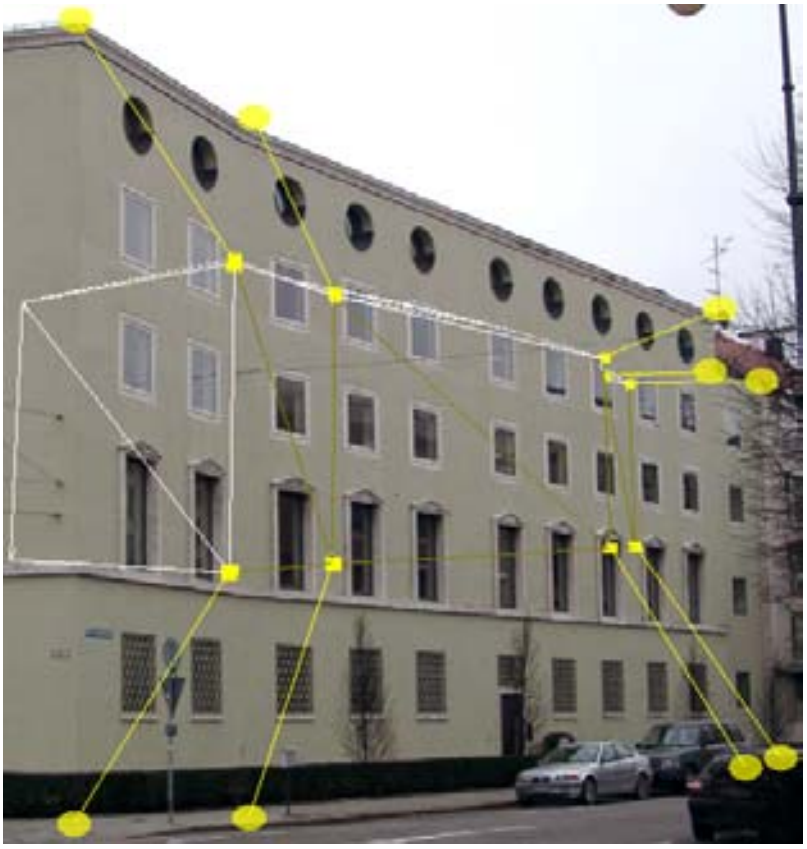
Align the Model

1. In the **Model Options** dialog, click the **Geometry Locked** icon to unlock the geometry.

   The vertices of the selected faces display as yellow boxes.

2. Drag each of these vertices so that they rest just outside of the corresponding building corners in the Active Image.

   NOTE: Again, several of the vertices in the Active image are occluded by incidental artifacts in the image. You must simply make your best guess as to where these vertices lie.



3. Click the **Align Model To Image** button on the **Model Options** dialog.

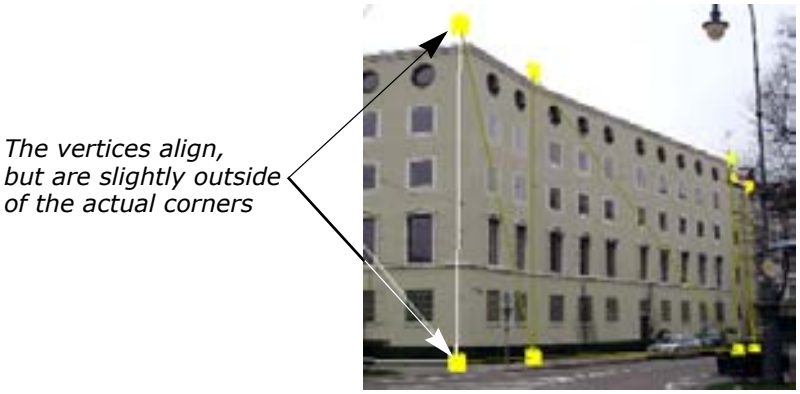
   The **Align Model to Image** function attempts to automatically align the selected vertices of the model to the placement you assigned on the Active Image. It does this by approximating the FOV and Perspective in the image. The greater the number of vertices that are selected, the better the estimated alignment.

   To return the model and image to the original FOV and perspective, click the return to default view button on the Texel Mapper toolbar.

   This is an inexact science, and you may need to readjust the vertices and realign the model to the image a few times before you get a suitable alignment.

4. Repeat step 2 and step 3 until the model is relatively well aligned with the feature in the image. For minor adjustments, rotate and zoom the model manually.

5. When you have a good alignment, hold the middle button and magnify the model so that it still lines up with the corners, but the model is slightly larger than the feature in the image. This allows you some leeway when you are fine-tuning the texture.



Extract and Map the Texture

Extracting and mapping textures, especially textures from perspective-distorted images, is an inexact science. It involves trail-and-error, so you may have to repeat these steps several times to achieve a satisfactory result. Also, your results may differ slightly from those shown in this tour.

1. Click the **Extract Texture** button on the **Model Options** dialog.

   The portion of the image that underlies the selected faces on the model is extracted, and creates a new Active Image, called Extract_0. This image may appear slightly warped, but this warping can be minimized in the mapping process.

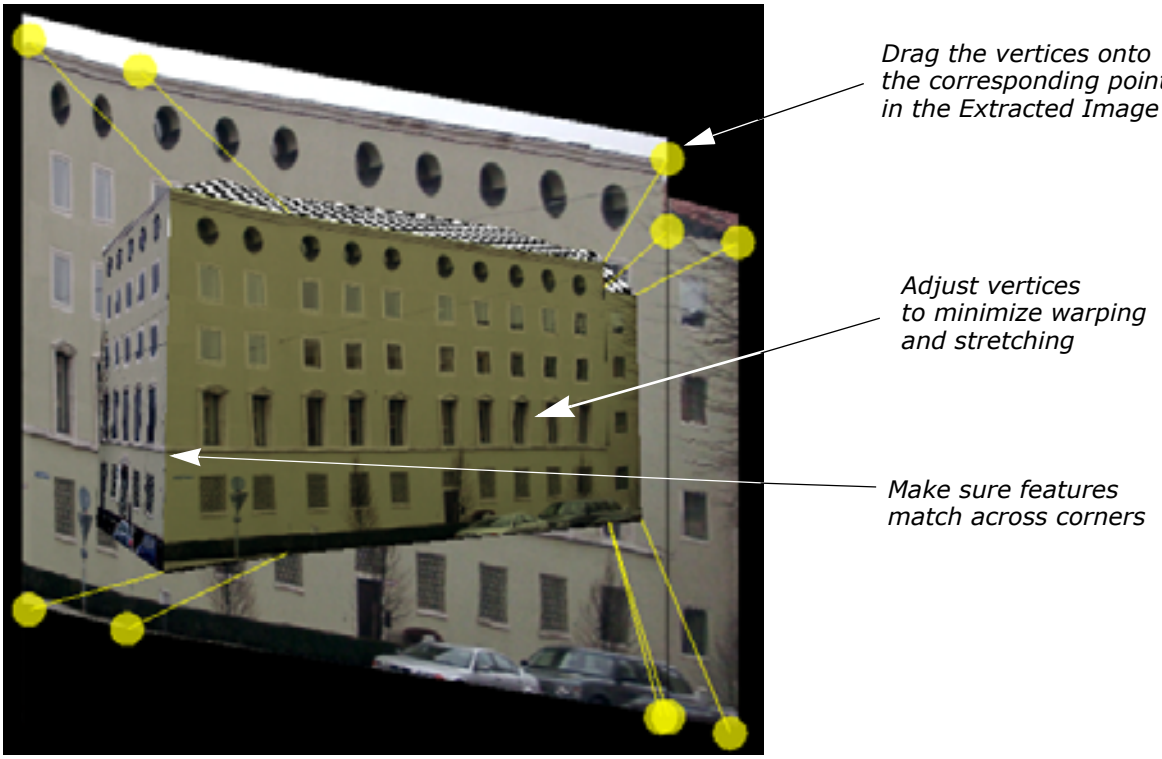
   If you are dissatisfied with the extracted texture for any reason, simply select karolinerplatz_right from the Active Image list and repeat the preceding steps in "Align the Model".

2. Once you have extracted an image that shows all of the vertices and appears relatively unwarped, return to **Affine Map Options** mode by clicking the Affine Map button .

3. Drag the vertices so that they accurately rest on the corresponding building corners in the image.

   As you move the vertices, the texture on the model warps and stretches.

4. Fine tune the position of each vertex to eliminate the worst of the warping and stretching. Also, watch to make sure that features that continue around corners match up.



5. Deselect the texturized faces of the model by right clicking outside of the model.

6. Save the model by selecting **File -> Save As -> Multigen OpenFlight Database** and selecting **texel_mapper_tour.flt** from the file list. Overwrite the existing file with your latest changes.

Texturize the Other Side of the Model

Repeat the above steps, using the **karolinenplatz_left** and the left side of the model. This side is slightly more challenging, as it contains fewer vertices and more perspective distortion.

Editing the Texture

One of the shortcomings of using photographs of actual buildings to texturize your model is that you also get artifacts in the pictures. In other words, you get a picture of the powerlines, lamp posts, and automobiles that happen to be parked in front of the building at the time the picture was taken.

The Texel Mapper provides an Image Edit utility to edit these artifacts out of the image and get a clean texture on the building.

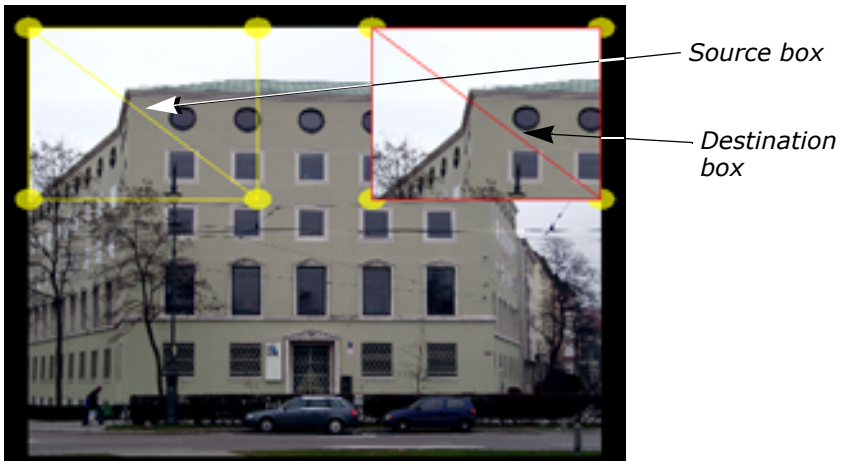
Display a Texture with Texture Picking Options

1. Rotate the model to display the front of the model.
2. Enter the Texture Picking Options mode by clicking the Texture Picking Options button on the Texel Mapper toolbar.
3. Right-click on the front of the model. The **karlolinerplatx_front** texture displays in the workspace.

Image Edit Options Mode

1. Enter the Image Edit Options mode by clicking the Image Edit Options button on the Texel Mapper toolbar.

   The model is hidden, and the active image displays with a yellow box (the Source Box) and a red box (the Destination Box). The portion of the image enclosed by the Source Box is used to replace the portion of the image in the Destination Box.

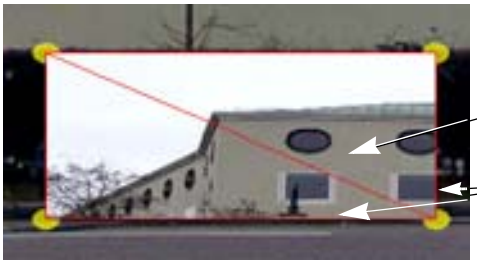


Remove an Automobile Artifact

There are two cars parked in front of the building. We will attempt to remove one of these artifacts from the image.

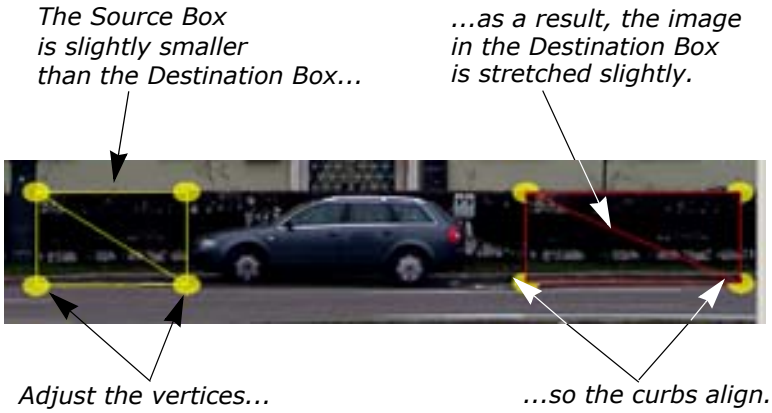
1. To move the Destination Box, drag each of the vertices so that they cover the blue compact car in the image.

Keep the vertices in their same relative positions. That is, make sure that the upper-left vertex remains in the upper-left position after you move the box. If you reverse any of these vertices, the image in the Destination Box will be appear (and be applied) inverted or as a mirror image of the Source Box.



2. Drag the vertices of the Source box so that they enclose an unobstructed portion of the hedge that is roughly the same size as the compact car.

3. Use the left mouse button to pan through the image, and the center mouse button to zoom in on the portion of the image that you are editing. Fine tune your Source and Destination Boxes so that



4. Select the **Preview** radio button on the **Image Edit Options** menu to see a preview of what the edited image will look like.

5. If you are satisfied with the Preview, click **Apply**. Otherwise, continue adjusting the vertices until you are satisfied.

   After you click **Apply**, you will see a **Clean Preview**. This preview shows you the result of the editing operation without the Source and Destination Boxes.

6. You may continue experimenting with the **Image Edit Options**, and remove the remaining car, the trees, the power lines, and the lamp post, if you wish. To resume editing, select the **Edit** radio button on the **Image Edit Options** menu.

7. To see the results of your editing on the model, enter the Model Options mode by clicking the button on the Texel Mapper toolbar.

   The model display. Note that the compact car (and any other artifact that you edited out) is no longer visible on the textures front of the building.

Tiling a Texture

Now you have textured the three faces of the building for which you have pictures. The other sides of the building, though still need textures, and there are no digital images for those faces. You need a simple way to quickly texturize the remaining sides.

This can be done by tiling a representative texture onto the remaining sides. Tiling a texture means repeating a simple, small pattern across a large area, like tiling a floor.

Adding the Texture to the Tile Library

The Texel Mapper includes a Tile Library for organizing and maintaining your collection of tiles. First, you add the new texture to the Tile Library.

1. Enter the Tile Options mode by clicking the Tile Options icon on the Texel Mapper toolbar.

   The **Tile Options** dialog displays.

2. Create a new Image Class by clicking the Add Class icon next to the **Image Class** dropdown list.

   The **New Image Class** dialog displays.

3. Enter **Building Sides** into the text box and click **OK**.

   Building Sides appears in the **Image Class** dropdown list.

4. To add an image to the Building Sides class, click the Add Image icon next to the **Image Name** dropdown list.

   A **File Selector** displays.

5. Select **JFIF** from the **Files of Type** dropdown list.

6. Select **karolinenplatz_texture.jpg** from the list of files.

7. On the **Options** tab, check **No Stretch**.

8. Click **OK**.

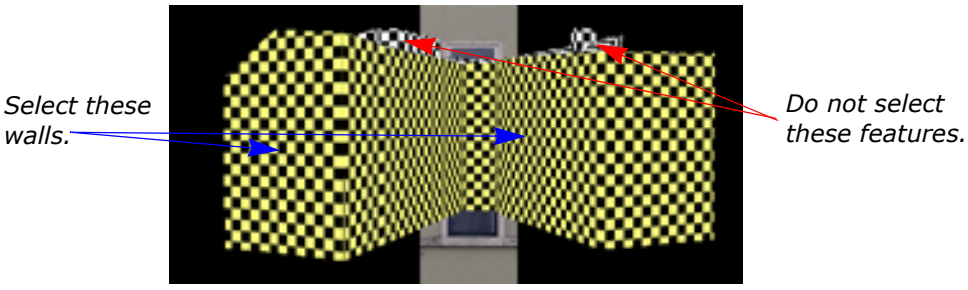
   The image **karolinenplatz_texture** is added to the **Building Sides** Image Class and displays in the **Texel Mapper** workspace.

Tiling Multiple Faces

Now you need to tile the image on the model. You will start by applying the texture to a several faces.

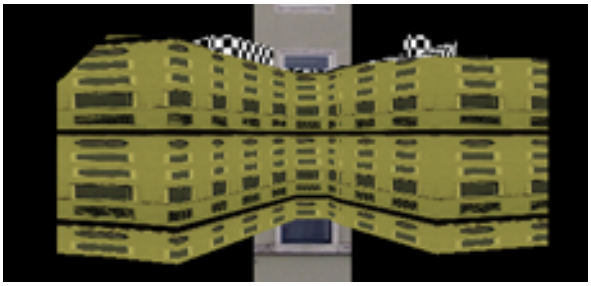
1. Rotate the model so that the rear of the building is visible.

2. Select all of the polygons that comprise the rear walls of the building.



3. Click the Apply Tile button on the Tile Options dialog.

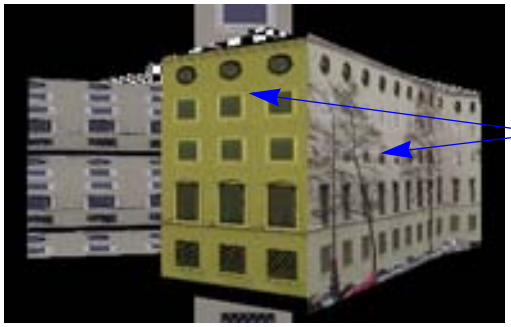
   The image is tiled onto the selected faces.



Scaling the Tiles

The texture you just tiled looks flattened and distorted. Now you will use the Tile Options to rescale the tiles to their correct proportions.

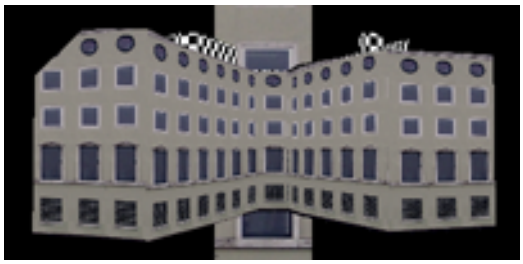
1. Select the right-rear face of the model.
2. Click the **Reset Tile Vertically** button. This optimizes the tile for vertical or near-vertical surfaces such as walls.
3. Click the Locked icon to unlock the aspect ratio. This allows you to scale the X and Y directions separately.
4. Drag the **Scale Y Direction** thumbwheel left until the tile appears to be stretched to fit the entire height if the building.
5. Adjust the **Move Y Direction** thumbwheel until the tile is centered on the model face.
6. Adjust the **Scale X Direction** and **Move X Direction** thumbwheels until the you have three tiles across the selected face.



The tiled texture is approximately the same scale as the mapped texture.

You will need to perform these last steps several times to get a good approximation.

7. Repeat these steps for each of the remaining four faces.



Add a new Image to the Library

Now that you have tiled the walls of the building, it is time to tile the roof. First, you will need to add a new Image Class and Image to the Tile Library.

1. Enter the Tile Options mode by clicking the Tile Options icon on the Texel Mapper toolbar.
   The **Tile Options** dialog displays.

2. Create a new Image Class by clicking the Add Class icon next to the **Image Class** dropdown list.
   The **New Image Class** dialog displays.

3. Enter **Roof** into the text box and click **OK**.
   Roof appears in the **Image Class** dropdown list.

4. To add an image to the Building Sides class, click the Add Image button next to the **Image Name** dropdown list.
   A **File Selector** displays.

5. Select **JFIF** from the **Files of Type** dropdown list.

6. Select **metal_roofing.jpg** from the list of files.
7. On the **Options** tab, check **No Stretch**.
8. Click **OK**.

   The image **metal_roofing** is added to the **Roof** Image Class and displays in the Texel Mapper workspace.

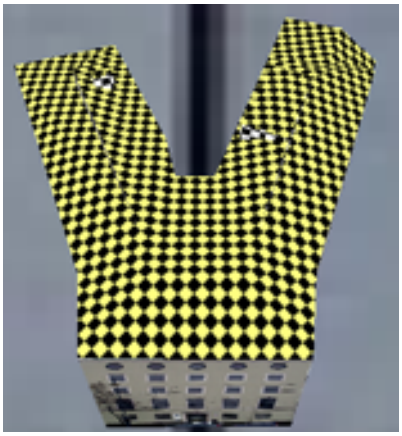
Autotiling the Rooftop

The Texel Mapper provides the ability to automatically tile all of the rooftops or walls on all of the models that are displayed in the workspace.

1. Enter the Autotile Options mode by clicking the Autotile button on the Texel Mapper toolbar.

   The **Autotile Options** dialog displays.
2. Select **Roof** from the **Geometry Type** dropdown list.
3. Check the **Apply To Locked Geometry** checkbox.

   All of the rooftop polygons on the model are highlighted.



4. Enter **1.000** in the **Scale** field and click **Apply**.

   The metal_roofing tile is uniformly applied to the roof of the model.
5. Click the **Clear Highlight** button.

Orient the Tiles

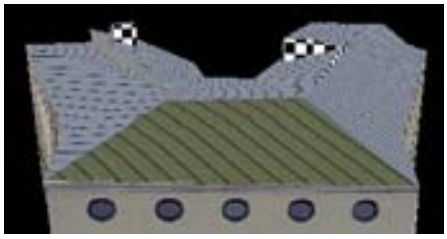
Now that the texture has been applied to the roof, you need to orient the tiles so that the lines in the tiled texture mimic those found on the actual building.

1. Enter the Tile Options mode by clicking the Tile Options icon on the Texel Mapper toolbar.

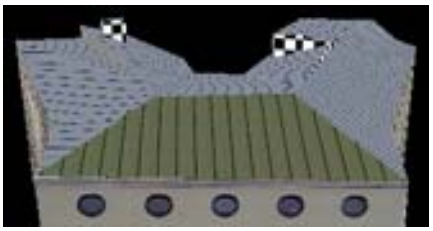
   The **Tile Options** dialog displays.

2. Select the roof face that borders the front of the building.

3. Adjust the **Rotate** thumbwheel until the tiled texture lines run perpendicular to the roofline.



Before orientation



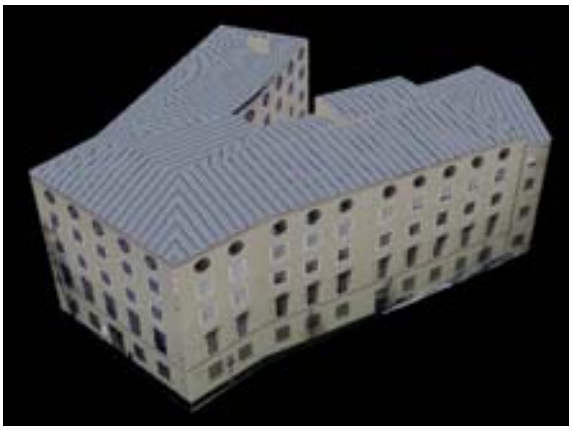
After orientation

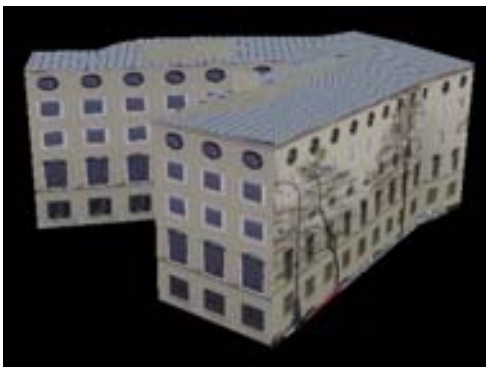
4. Continue to select, rotate, and move all of the roof faces of the model until you have them all oriented to your satisfaction.

5. Look for untexturized faces and map blank wall textures to them.

6. Save the model by selecting **File -> Save As -> Multigen OpenFlight Database...** and entering **texel_tour_complete.flt** in the filename textbox.

   You have a fully textured model of a building, ready for inclusion in any 3D application.





Reference Material

Feature Projects and Classes

Introduction

This chapter provides information regarding the Stereo Analyst feature project and feature classes.

Stereo Analyst Feature Project and Project File

A Stereo Analyst feature project is a mechanism for managing and organizing all of the information associated with a digital mapping project created in Stereo Analyst. A feature project is a directory that contains the following items:

- an ESRI 3D Shapefile (*.shp) for each user-selected feature class,
- a backup ESRI 3D Shapefile file (*_backup.shp) for each 3D Shapefile, and
- a feature class file (*.fcl) for each user-selected feature class,
  - A feature class file contains detailed information associated with a feature class such as color, display attributes, and feature attributes. The name of the feature class file corresponds to the name of the 3D Shapefile.

See "Default Stereo Analyst Feature Classes" for important information regarding maintenance of original .fcl files distributed with Stereo Analyst.

- a database (dBase) file (*.dbf) for each 3D Shapefile,
  - The dBase file contains all of the attribute table information associated with a 3D Shapefile.
- an index (*.shx) file for each 3D Shapefile,
  - The index file allows direct access to records in the main 3D Shapefile.
- a projection file (*.prj) for each 3D Shapefile,
  - The projection file contains all of the projection and unit information associated with a 3D Shapefile.
- an RDX file for each 3D Shapefile, and
- a Feature Project file (*.fpj).

- The feature project file is an ASCII file containing references to images, feature classes, etc. The name of the feature project file corresponds to the name of the feature project directory.

A Stereo Analyst feature project file (*.fpj) contains all of the feature class and image information associated with a feature project. A feature project file contains references to the following information:

- feature class files,
- LPS Project Manager block file or stereopair (STP) files, and
- specific references to the individual images contained within an LPS Project Manager block file or STP file.

When a feature project opens in Stereo Analyst, all of the information contained within the feature project file is referenced for subsequent display and use in Stereo Analyst. The following example illustrates a feature project containing 20 unique feature classes and two separate LPS Project Manager block files (each block file containing one stereopair).

```
FeatureProjectDescription:ìì
AssociatedFeatureClasses {
ìd:/stereo analyst/western_campus//building1.fclî,
ìd:/stereo analyst/western_campus//building2.fclî,
ìd:/stereo analyst/western_campus//building3.fclî,
ìd:/stereo analyst/western_campus//building_4.fclî,
ìd:/stereo analyst/western_campus//race.fclî,
ìd:/stereo analyst/western_campus//church.fclî,
ìd:/stereo analyst/western_campus//dual_hwy.fclî,
ìd:/stereo analyst/western_campus//dual_hwy_m.fclî,
ìd:/stereo analyst/western_campus//second_hwy.fclî,
ìd:/stereo analyst/western_campus//bridge.fclî,
ìd:/stereo analyst/western_campus//light_rd.fclî,
ìd:/stereo analyst/western_campus//ind_cont.fclî,
ìd:/stereo analyst/western_campus//inter_cont.fclî,
ìd:/stereo analyst/western_campus//sup_cont.fclî,
ìd:/stereo analyst/western_campus//int_river.fclî,
ìd:/stereo analyst/western_campus//int_stream.fclî,
ìd:/stereo analyst/western_campus//per_river.fclî,
ìd:/stereo analyst/western_campus//vineyard.fclî,
ìd:/stereo analyst/western_campus//orchard.fclî,
ìd:/stereo analyst/western_campus//woods.fclî, }
ProjectDate:      ì(null)î
ProjectScale:     0
ProjectLocation:  ì(null)î
SceneName:        ìd:/stereo analyst/stereo analyst
data/western/western_block2.blkî
SceneData { ìlayernameî ìd:/stereo analyst/stereo
analyst data/western/western_block2.blkî ìlayertypeî
ìblockî ìblockfilenameî ìd:/stereo analyst/stereo
analyst data/western/western_block2.blkî
ìleftstretchimageî ì1î ìleftinvertcolorsî ì0î
ìleftnumtotalbandsî ì1î ìleftnumdisplaybandsî ì1î ì0î
ìleftimagenameî ìd:/stereo analyst/stereo analyst
data/western/253.imgî ìrightstretchimageî ì1î
ìrightinvertcolorsî ì0î ìrightnumtotalbandsî ì1î
ìrightnumdisplaybandsî ì1î ì0î ìrightimagenameî
ìd:/stereo analyst/stereo analyst
data/western/254.imgî }
ImageHistory {
                  ImageName:ìd:/stereo analyst/stereo
```

```
analyst data/western/western_block1.blkî  ìTRUEî
ìFALSEî

                    LayerArgs { ìlayernameî ìd:/stereo
analyst/stereo analyst
data/western/western_block1.blkî ìlayertypeî ìblockî
ìblockfilenameî ìd:/stereo analyst/stereo analyst
data/western/western_block1.blkî ìleftstretchimageî
ì1î ìleftinvertcolorsî ì0î ìleftnumtotalbandsî ì1î
ìleftnumdisplaybandsî ì1î ì0î ìleftimagenameî
ìd:/stereo analyst/stereo analyst
data/western/251.imgî ìrightstretchimageî ì1î
ìrightinvertcolorsî ì0î ìrightnumtotalbandsî ì1î
ìrightnumdisplaybandsî ì1î ì0î ìrightimagenameî
ìd:/stereo analyst/stereo analyst
data/western/252.imgî } StereoPairs { ì251.img &
252.imgî ìTRUEî ìFALSEî }

                    ImageName:ìd:/stereo analyst/stereo
analyst data/western/western_block2.blkî  ìTRUEî ìTRUEî

                    LayerArgs { ìlayernameî ìd:/stereo
analyst/stereo analyst
data/western/western_block2.blkî ìlayertypeî ìblockî
ìblockfilenameî ìd:/stereo analyst/stereo analyst
data/western/western_block2.blkî ìleftstretchimageî
ì1î ìleftinvertcolorsî ì0î ìleftnumtotalbandsî ì1î
ìleftnumdisplaybandsî ì1î ì0î ìleftimagenameî
ìd:/stereo analyst/stereo analyst
data/western/253.imgî ìrightstretchimageî ì1î
ìrightinvertcolorsî ì0î ìrightnumtotalbandsî ì1î
ìrightnumdisplaybandsî ì1î ì0î ìrightimagenameî
ìd:/stereo analyst/stereo analyst
data/western/254.imgî } StereoPairs { ì253.img &
254.imgî ìTRUEî ìTRUEî }

}
```

Stereo Analyst Feature Classes

The default Stereo Analyst feature classes are based on 1:24,000 USGS topographic map symbols used for the photogrammetric compilation of topographic and planimetric maps by the USGS. The default feature classes serve as templates used for collecting 3D features in Stereo Analyst. During the creation of a Stereo Analyst feature project, various feature classes are selected. The selected feature classes are stored as feature class files (*.fcl) in a feature project directory you select. Unique color and attribute information can be defined for each selected feature class.

General Information

The contents of a Stereo Analyst feature class vary according to the feature type. Point, polyline, and polygon feature class files contain different information. The following general information characterizes each feature class.

- **Feature Class Name.** The feature class name can be defined within the **General** tab of the Create Custom Class dialog. The feature class name is the name displayed within the Feature Class Palette. The feature class name is also used as the name for the output 3D Shapefile.

- **Feature Class Category.** Stereo Analyst provides a default set of feature class categories. Feature class categories contain a series of feature classes. A feature class category can be created within the **General** tab of the Create Custom Class dialog.

- **Icon File.** The icon file is a bitmap (*.bmp) file used to represent the feature class in the feature class palette. The icon file must be a bitmap file.

- **Feature Code.** The feature code is a unique numeric value used to identify and index a feature class.

- **Feature Display Attributes.** The feature display attributes characterize how a given feature class displays once it has been collected.

- **Feature Attributes.** The feature attributes define the attributes to be used for the specific feature class. The following information is used to characterize each feature attribute:

  - type of feature attribute (STRING, INTEGER, FLOAT, DATE),
  - maximum width of attribute display, and
  - number of decimal places used to display each feature attribute.

Point Feature Class

A Stereo Analyst feature class file (*.fcl) for a point feature contains the following information:

- Feature Class Name,

See "General Information".

- Feature Class Category,

- Icon File,

- Feature Code,

- Feature Shape,

  - The feature shape describes the shape: POINT.

- Point Display Attributes, and

  - The point display attributes characterize the color used to display the point feature in Stereo Analyst.

- Point Feature Attributes.

  - The point feature attributes define the attributes to be used for the specific point feature class. The following information is used to characterize each point feature attribute:

- type of point feature attribute (STRING, INTERGER, FLOAT, DATE),
- maximum width of attribute display, and
- number of decimal places used to display the attribute.

The following feature class provides an example of a **Horizontal Control** point feature class:

```
FeatureClass:     ìHoriz. Controlî
Category:         ìHorizontal Controlî
IconFile:         ì1.bmpî
FeatureCode:      1000
FeatureShape:     POINT\
PointDrawAttributes {
Color:            1.00, 0.00, 0.00;
}
FeatureAttributes {
                  ìFIDîINTEGER 5 0;
                  ìAvg_Zî FLOAT 12 2; }
```

Polyline Feature Class

A Stereo Analyst feature class file (*.fcl) for a polyline feature contains the following information:

- Feature Class Name,

See "General Information".

- Feature Class Category,
- Icon File,
- Feature Code,
- Feature Shape,
  - The feature shape describes the shape: POLYLINE.
- Polyline Display Attributes, and
  - The polyline display attributes characterize the color and line width used to display the polyline feature in Stereo Analyst.
- Polyline Feature Attributes.
  - The polyline feature attributes define the attributes to be used for the specific polyline feature class. The following information is used to characterize each polyline feature attribute:
  - type of polyline feature attribute (STRING, INTERGER, FLOAT, DATE),
  - maximum width of attribute display, and

- number of decimal places used to display the attribute.

The following feature class provides an example of a **Dual Highway** polyline feature class:

```
FeatureClass:     ìDual Highwayî
Category:         ìRoads and Related Featuresî
IconFile:         ì105.bmpî
FeatureCode:      13005
FeatureShape:     POLYLINE
PolylineDrawAttributes {
Color:            1.00, 0.00, 0.00;
LineWidth:        2;
}
FeatureAttributes {
                  ìFIDî INTEGER 5 0;
                  ìLengthî FLOAT 1 22;
                  ìAvg_Zî FLOAT 12 2; }
```

Polygon Feature Class

A Stereo Analyst feature class file (*.fcl) for a polygon feature contains the following information:

- Feature Class,

See "General Information".

- Category,
- Icon File,
- Feature Code,
- Feature Shape,
  - The feature shape describes the shape: POLYGON.
- Polygon Display Attributes, and
  - The polygon display attributes characterize the fill color, opacity, border color, and border width used to display the polygon feature in Stereo Analyst.
- Polygon Feature Attributes.
  - The polygon feature attributes define the attributes to be used for the specific polygon feature class. The following information is used to characterize each polygon feature attribute:
  - type of polygon feature attribute (STRING, INTERGER, FLOAT, DATE),
  - maximum width of attribute display, and
  - number of decimal places used to display the attribute.

The following feature class provides an example of a **Building 1** polygon feature class.

```
FeatureClass:     ìBuilding 1î
Category:         ìBuildings and Related Featuresî
IconFile:         ì81.bmpî
FeatureCode: 12000
FeatureShape:     POLYGON
PolygonDrawAttributes {
                  DrawFilled; FillColor:0.00, 0.00,
0.00;
                  Opacity: 40; DrawBorder;
BorderColor:      1.00, 1.00, 1.00;
                  BorderWidth: 1;
}
FeatureAttributes { ìFIDîINTEGER50; ìAreaîFLOAT122;
ìPerimeterî       FLOAT122; ìAvg_ZîFLOAT122; }
```

Default Stereo Analyst Feature Classes

The default Stereo Analyst feature classes can be located within the <IMAGINE_HOME>/etc/FeatureClasses directory. When a feature project is created, the feature classes you select are copied into the feature project directory. The addition of new feature attribute information does not affect the template feature class files.

It is highly recommended that the original feature class files not be edited or modified.

If you edit feature class properties in a feature project, the next time you save the project, you are prompted as to whether or not you want to save the display properties and attributes changes to the global feature class. If you select Yes, the global feature class is permanently altered. If you select No, then the display properties and attributes changes are only saved to the feature class in the current project.

If you import a feature class with the same name but different attributes from a feature class already existing in the global feature class list in Stereo Analyst, you are prompted as to whether or not you want to use the global feature class properties and attributes instead of the local feature class properties and attributes. Choose Yes and discard attributes different from those stored in the global feature class list. Choose No and the attributes in the feature class remain, and a new class is added to the local feature project only.

Table 9 lists the default feature classes provided by Stereo Analyst. Classes are divided by feature class categories, which are indicated by shaded boxes.

Table 9: Stereo Analyst Default Feature Classes

Feature	Feature Class File Name (*.fcl)	Stereo Analyst Name	Bitmap	FCODE	Feature Type
Horizontal Control					
With third order or better	horiz_contrl	Horiz. Control	1.bmp	1000	Point
Checked spot elevation	c_spt_elev	Chkd. Spot Elev.	2.bmp	1001	Point
Unmonumented	unmonumented	Unmonumented	3.bmp	1002	Point
Vertical Control					
Third order or better, with tablet	v_control_3	V.Control 3rd	4.bmp	1003	Point
Third order or better, recoverable mark	r_v_control_3	Rec. V. Cont 3rd	5.bmp	1004	Point
Spot elevation	spot_elev	Spot Elevation	6.bmp	1005	Point
Boundary Monument					
With tablet	b_mon_w_tab	Bound. Mon. Tab	7.bmp	1006	Point
Without tablet	b_monument	Bound. Mon.	8.bmp	1007	Point
U.S. mineral or location monument	us_min_mon	U.S. Mineral Mon.	10.bmp	1008	Point
Topographic Contours					
Intermediate	inter_cont	Inter. Contour	11.bmp	2000	Polyline
Index	ind_cont	Index Contour	12.bmp	2001	Polyline
Supplementary	sup_cont	Suppl. Contour	13.bmp	2002	Polyline
Depression	depression	Depression	14.bmp	2003	Polygon
Cut/Fill	cut	Cut/Fill	15.bmp	2004	Polygon
Boundaries					
National	nat_boundary	National Boundary	17.bmp	3000	Polyline
State or territorial	state_bound	State Boundary	18.bmp	3001	Polyline
County or equivalent	county_bound	County Boundary	19.bmp	3002	Polyline
Civil township or equivalent	town_boundary	Town Boundary	20.bmp	3003	Polyline
Incorporated city or equivalent	city_bound	City Boundary	20.bmp	3004	Polyline
Park, reservation, or monument	park_boundary	Park Boundary	21.bmp	3005	Polyline
Small park	sm_park_bound	Small Park Bound.	22.bmp	3006	Polyline
U.S. Public Land Survey System					

Table 9: Stereo Analyst Default Feature Classes (Continued)

Feature	Feature Class File Name (*.fcl)	Stereo Analyst Name	Bitmap	FCODE	Feature Type
Township or range line	town_line	US Township Line	23.bmp	4000	Polyline
Township or range line - location doubtful	location_doubt	Location Doubtful	24.bmp	4001	Polyline
Section line	section-line	US Section LIne	25.bmp	4002	Polyline
Other Land Surveys					
Township or range line	other_t_line	Other Town Line	28.bmp	4003	Polyline
Section line	other_sec_line	Other Sect. Line	29.bmp	4005	Polyline
Land grant or mining claim; monument	mining_claim	Mining Claim	30.bmp	4006	Polyline
Fence line	fence_line	Fence Line	31.bmp	4007	Polyline
Surface Features					
Levee	levee	Levee	32.bmp	5000	Polyline
Sand or mud area, dunes, or shifting sand	sand	Sand	33.bmp	5001	Polygon
Intricate surface area	int_surface	Intricate Surface	34.bmp	5002	Polygon
Gravel beach or glacial moraine	grav_beach	Gravel Beach	35.bmp	5003	Polygon
Tailings pond	tail_pond	Tailings Pond	36.bmp	5004	Polygon
Mines and Caves					
Quarry or open pit maine	quarry	Quarry	37.bmp	6000	Polygon
Gravel, sand, clay, or borrow pit	gravel_pit	Gravel Pit	39.bmp	6001	Polygon
Mine tunnel or cave entrance	mine_tunnel	Mine Tunnel	40.bmp	6002	Polyline
Prospect; mine shaft	prospect	Prospect	41.bmp	6003	Polygon
Mine dump	mine_dump	Mine Dump	42.bmp	6004	Polygon
Tailings	tailings	Tailings	43.bmp	6005	Polygon
Vegetation					
Woods	woods	Woods	44.bmp	7000	Polygon
Scrub	scrub	Scrub	45.bmp	7001	Polygon
Orchard	orchard	Orchard	47.bmp	7002	Polygon
Vineyard	vineyard	Vineyard	47.bmp	7003	Polygon
Mangrove	mangrove	Mangrove	48.bmp	7004	Polygon
Coastal Features					
Rock or coral reef	coral	Coral Reef	53.bmp	8000	Polygon
Group of racks bare or awash	exp_rocks	Exposed Rocks	54.bmp	8001	Polygon

Table 9: Stereo Analyst Default Feature Classes (Continued)

Feature	Feature Class File Name (*.fcl)	Stereo Analyst Name	Bitmap	FCODE	Feature Type
Breakwater, pier, jetty, or wharf	breakwater	Breakwater	56.bmp	8002	Polyline
Seawall	seawall	Seawall	58.bmp	8003	Polyline
Bathymetric Features					
Area exposed at mean low tide	area_expo	Area Exposed	59.bmp	9000	Polyline
Channel	channel	Channel	60.bmp	9001	Polyline
Offshore oil or gas; well; platform	offshore	Offshore oil	61.bmp	9002	Point
Sunken rock	sunken_rock	Sunken Rock	62.bmp	9003	Point
Rivers, Lakes, and Canals					
Intermittent stream	int_stream	Int. Stream	63.bmp	10000	Polyline
Intermittent river	int_river	Inter. River	64.bmp	10001	Polyline
Perennial stream	per_stream	Per. Stream	65.bmp	10002	Polyline
Perennial river	per_river	Per. River	66.bmp	10003	Polyline
Small falls; small rapids	small_rapids	Small Rapids	67.bmp	10004	Polyline
Large falls; large rapids	lar_rapids	Large Rapids	68.bmp	10005	Polyline
Perennial lake	per_lake	Per. Lake	69.bmp	10006	Polygon
Intermittent lake	int_lake	Int. Lake	70.bmp	10007	Polygon
Pond	pond	Pond	71.bmp	10008	Polygon
Dry lake	dry_lake	Dry Lake	72.bmp	10009	Polygon
Narrow wash	narr_wash	Narrow Wash	73.bmp	10010	Polyline
Wide wash	wide_wash	Wide Wash	74.bmp	10011	Polyline
Well or spring; spring or seep	well	Well (water)	76.bmp	10012	Point
Submerged Areas and Bogs					
Marsh or swamp	marsh	Marsh	77.bmp	11000	Polygon
Submerged marsh or swamp	sub_mar	Sub. Marsh	78.bmp	11001	Polygon
Wooded marsh or swamp	wood_marsh	Wood Marsh	79.bmp	11002	Polygon
Submerged wooded marsh or swamp	su_w_marsh	Sub. W. Marsh	79.bmp	11003	Polygon
Rice field	rice_field	Rice Field	80.bmp	11004	Polygon
Buildings and Related Features					
Building 1	building1	Building 1	81.bmp	12000	Polygon
Building 2	building2	Building 2	82.bmp	12001	Polygon
Building 3	building3	Building 3	83.bmp	12002	Polygon
Building 4	building_4	Building 4	84.bmp	12003	Polygon
School	school	School	85.bmp	12004	Polygon

Table 9: Stereo Analyst Default Feature Classes (Continued)

Feature	Feature Class File Name (*.fcl)	Stereo Analyst Name	Bitmap	FCODE	Feature Type
Church	church	Church	86.bmp	12005	Polygon
Built-up area	built-up	Built Up Area	87.bmp	12006	Polygon
Racetrack	race	Racetrack	88.bmp	12007	Polygon
Airport	airport	Airport	89.bmp	12008	Polygon
Landing strip	landing	Landing Strip	90.bmp	12009	Polygon
Well (other than water); windmill	well_b	Well (other)	91.bmp	12010	Point
Tanks	tanks	Tanks	92.bmp	12011	Point
Covered reservoir	reservoir	Reservoir	93.bmp	12012	Polygon
Gaging station	gaging	Gaging Sta.	94.bmp	12013	Point
Buildings and Related Features (Continued)					
Landmark object (feature as labelled)	landmark	Landmark	95.bmp	12014	Polygon
Campground	campground	Campground	97.bmp	12015	Polygon
Picnic area	picnic	Picnic Area	98.bmp	12016	Polygon
Cemetery	cemetery	Cemetery	99.bmp	12017	Polygon
Roads and Related Features					
Primary highway	pri_highway	Primary Highway	100.bmp	13000	Polyline
Secondary highway	second_hwy	Second. Hwy	101.bmp	13001	Polyline
Light duty road	light_rd	Light Duty Road	102.bmp	13002	Polyline
Unimproved road	unimpro_rd	Unimproved Road	103.bmp	13003	Polyline
Trail	trial [*sic*]	Trail	104.bmp	13004	Polyline
Dual highway	dual_hwy	Dual Highway	105.bmp	13005	Polyline
Dual highway with median strip	dual_hwy_m	Dual Hwy. Strip	106.bmp	13006	Polyline
Road under construction	rd_construct	Road Construct.	107.bmp	13007	Polyline
Underpass; overpass	underpass	Underpass	108.bmp	13008	Polyline
Bridge	bridge	Bridge	109.bmp	13009	Polyline
Drawbridge	drawbridge	Drawbridge	111.bmp	13010	Polyline
Tunnel	tunnel	Tunnel	112.bmp	13011	Polyline
Railroads and Related Features					
Standard gauge single track; station	rail_single	Railroad Single	113.bmp	14000	Polyline
Standard gauge multiple track	mult_rail	Multiple Railroad	114.bmp	14001	Polyline
Railroad in street	rail_street	Rail in Street	119.bmp	14002	Polyline
Transmission LInes and Pipelines					

Table 9: Stereo Analyst Default Feature Classes (Continued)

Feature	Feature Class File Name (*.fcl)	Stereo Analyst Name	Bitmap	FCODE	Feature Type
Power transmission line; pole; tower	power_line	Power Line	120.bmp	15000	Polyline
Telephone line	tele_line	Telephone Line	121.bmp	15001	Polyline
Aboveground oil or gas pipeline	ab_gas	Above Gas Line	122.bmp	15002	Polyline
Underground oil or gas pipeline	under_gas	Under Gas Line	123.bmp	15003	Polyline

Using Stereo Analyst ASCII Files

Introduction

American Standard Code for Information Interchange (ASCII) files containing GIS feature and attribute information can be both imported into and exported from Stereo Analyst. In order to import an ASCII file, the input ASCII file must conform to the standards defined by Stereo Analyst. ESRI 3D Shapefiles can be exported as descriptive ASCII files for use in other mapping and CAD packages such as MicroStation, AutoCAD, and TerraModel.

ASCII Categories

The Stereo Analyst ASCII file can be broken down into the following categories: introductory text, number of classes, shape class number, shape class 2, and shape class n.

Introductory Text

The introductory text introduces the Stereo Analyst ASCII file.

Number of Classes

This value states the number of feature classes used and defined within the Stereo Analyst feature project.

Shape Class Number

Shape Class Number has additional categories.

FCODE

FCODE (that is, Feature Code) is the primary index used to define a unique feature class. Each feature class in Stereo Analyst has a unique feature code.

Shape Type

The shape type defines the type of feature that has been collected. This includes point and multiple point features (for example, 3D_POINT shape type), polygon features (for example, 3D_POLYGON shape type), and polyline features (for example, 3D_ARC shape type).

Number of Attributes

The number of attributes is defined within the **Feature Attributes** tab of the Feature Project dialog. The number of attributes includes the default Stereo Analyst attributes for a given feature type plus the attributes you define. Each feature type has the following attribute fields:

- Point and multiple point features have a default Feature ID (FID) and Avg_Z attribute field.
- Polyline features have a default FID, Length, and AvgZ attribute field.

- Polygon features have a default FID, Area, Perimeter, and AvgZ attribute field.
- Parallel polyline features have a default FID, Length, AvgZ, and Width attribute field.

Attribute Description

The attribute description fields define the characteristics associated with a given attribute. This includes:

- type of attribute (for example, floating, real, integer),
- width (that is, number) of characters used to store the attribute string,
- the number of decimal places used to display and store the attribute value (if numeric), and
- name of the attribute.

The following is an example:

0) type: NUMERIC width: 5 numdecs: 0 name: "FID"

1) type: FLOAT width: 12 numdecs: 2 name: "Area"

2) type: FLOAT width: 12 numdecs: 2 name: "Perimeter"

3) type: FLOAT width: 12 numdecs: 2 name: "Avg_Z"

In this example, the first attribute is FID. Its display width is 5 characters and has 0 decimal places (numdecs). The second attribute is Area and it has a display width of 12 characters and contains 2 decimal places to the right. The third attribute is Perimeter and it has a display width of 12 characters and contains 2 decimal places to the right. The fourth attribute is AvgZ and it has a display width of 12 characters with 2 decimal places to the right.

Number of Shapes

This value indicates the number of shapes collected for the specific feature class. For example, if 20 houses were collected for the residential feature class, the number of shapes would be 20.

Shape Number

The shape number value states the shape that is described in the following description.

- Attribute Values. The attribute value for a given attribute is a series of alpha-numeric characters which has been automatically computed by Stereo Analyst (for example, AvgZ) or input by you (for example, the address of shape 354 is 741 Pacific Ave.). The following is an example of attribute values:

  0) 2.0

  1) 3001.5

  2) 220.57

  3) 256.22

In this example, the 0) attribute is FID and the value is 2.0. The 1) attribute is Area and the value is 3001.5. The 2) attribute is Perimeter and the value is 220.57. The 3) attribute is Avg_Z and the value is 256.22.

- Number of Parts. This value indicates the number of parts or feature elements associated with a given feature. A Part is also referred to as a feature element. For example, a building feature can have several feature elements associated with it. A feature element is a feature (for example, point, polyline, polygon) having an association with an existing feature. Therefore, when you select a feature within Stereo Analyst, all of the elements (if they are available) associated with the feature are selected.

- Part Number. This value indicates which part is described in the following portion of the ASCII file.

  Number of Points. The number of points is the number of vertices associated with a feature part. The following example illustrates 5 points (that is, vertices) associated with a feature.

  0) 477632.419597 4761198.995795 249.739925 0.000000

  1) 477674.118857 4761258.376408 248.880872 0.000000

  2) 477691.239580 4761246.461239 242.856737 0.000000

  3) 477648.942288 4761185.853104 242.626527 0.000000

  4) 477632.419597 4761198.995795 249.739925 0.000000

  Each row of information contains Point ID, X, Y, Z, and 0 (indicating the end of the line).

- Part Number 2 (repeat for each feature element or part comprising the specific feature).

  Number of Points (Repeat as above).

- Part Number N (repeat for each feature element or part comprising the specific feature).

  Number of Points (Repeat as above).

Shape Number 2

Shape Number 2 Description (repeat for each shape collected for the given feature class).

Shape Number N

Shape Number N Description (repeat for each shape collected for the given feature class).

Shape Class 2

Shape Class 2 (repeat for the second feature class defined and collected within Stereo Analyst).

Shape Class N

Shape Class N (repeat for each feature class defined and collected within Stereo Analyst).

ASCII File Example

The following example pertains to a Stereo Analyst Feature Project having the following characteristics:

- Eleven feature classes are defined within the Stereo Analyst feature project. Only five feature classes have been used to collect features. This includes shape class 1 (building1), shape class 2 (building2), shape class 3 (pri_highway), shape class 7 (unmonumented), and shape class 10 (woods).
- Shape Class 1 is a polygon feature class containing two 3D polygon shapes (for example, building1). Each building shape has five points (that is, vertices) associated with it. The 3D polygon shape has four attributes (that is, FID, Area, Perimeter, AvgZ).
- Shape Class 2 is a polygon feature class containing one 3D polygon shape (for example, building2). The polygon shape has twelve points (that is, vertices) associated with it. The 3D polygon shape has four attributes (that is, FID, Area, Perimeter, AvgZ).
- Shape Class 3 is a polyline feature class containing one 3D polyline shape (for example, primary highway). The polyline shape has three attributes (that is, FID, Length, AvgZ) and seven points (that is, vertices).
- Shape Class 7 is a point feature class (for example, unmonumented control) containing seven 3D point shapes. The point shape has two attributes (that is, FID, AvgZ), and each shape has one point (that is, vertex) associated with it.
- Shape Class 10 is a polygon feature class (that is, woods) containing one 3D polygon shape. The 3D polygon shape has four attributes (that is, FID, Area, Perimeter, AvgZ), and the 3D polygon shape has nine points (that is, vertices) associated with it.

The Stereo Analyst ASCII file begins here:

```
// Stereo Analyst 3D ascii shapes file. Version x.x
# This file is in Stereo Analyst 3D ascii format and
should
# not be altered. The format of this file could change
in
# future versions of Stereo Analyst

Number of Classes: 11

Shape Class 1 : ìbuilding1î
FCode 12000
Shape Type: 3D_POLYGON
Number of Attributes: 4
  0) type: NUMERIC width: 5 numdecs: 0 name: ìFIDî
  1) type: FLOAT width: 12 numdecs: 2 name: ìAreaî
  2) type: FLOAT width: 12 numdecs: 2 name: ìPerimeterî
  3) type: FLOAT width: 12 numdecs: 2 name: ìAvg_Zî
Number of Shapes: 2
  Shape 0
  Attribute Values:
    0) 1.000000
    1) 1535.400000
    2) 188.440000
    3) 246.030000
  Number of Parts: 1
    Part 0
    Number of Points: 5
      0) 477632.419597 4761198.995795 249.739925
0.000000
      1) 477674.118857 4761258.376408 248.880872
0.000000
      2) 477691.239580 4761246.461239 242.856737
0.000000
      3) 477648.942288 4761185.853104 242.626527
0.000000
      4) 477632.419597 4761198.995795 249.739925
0.000000
  Shape 1
  Attribute Values:
    0) 2.000000
    1) 3001.500000
    2) 220.570000
    3) 256.220000
  Number of Parts: 1
    Part 0
    Number of Points: 5
      0) 477715.040049 4761423.312186 254.413795
0.000000
      1) 477773.206585 4761413.022898 259.199663
0.000000
      2) 477782.550252 4761460.154519 258.961248
0.000000
      3) 477721.068481 4761473.489381 252.301078
0.000000
      4) 477715.040049 4761423.312186 254.413795
0.000000

Shape Class 2 : ìbuilding2î
FCode 12001
Shape Type: 3D_POLYGON
Number of Attributes: 4
  0) type: NUMERIC width: 5 numdecs: 0 name: ìFIDî
  1) type: FLOAT width: 12 numdecs: 2 name: ìAreaî
```

```
  2) type: FLOAT width: 12 numdecs: 2 name: ìPerimeterî
  3) type: FLOAT width: 12 numdecs: 2 name: ìAvg_Zî
Number of Shapes: 1
  Shape 0
  Attribute Values:
    0) 1.000000
    1) 808.480000
    2) 129.830000
    3) 263.790000
  Number of Parts: 1
    Part 0
    Number of Points: 12
      0) 477696.910594 4761586.826069 262.175821
0.000000
      1) 477702.250185 4761602.537792 263.426152
0.000000
      2) 477714.423688 4761600.282062 265.504668
0.000000
      3) 477716.098500 4761607.085565 266.890308
0.000000
      4) 477728.114636 4761604.300293 262.354671
0.000000
      5) 477724.339682 4761595.227101 263.610381
0.000000
      6) 477735.601556 4761593.899420 265.574982
0.000000
      7) 477732.200530 4761583.888528 256.712508
0.000000
      8) 477724.137993 4761583.551767 264.496121
0.000000
      9) 477721.404243 4761572.958093 264.389131
0.000000
      10) 477709.656544 4761572.711264 266.593709
0.000000
      11) 477696.910594 4761586.826069 262.175821
0.000000

Shape Class 3 : ìpri_highwayî
FCode 13000
Shape Type: 3D_ARC
Number of Attributes: 3
  0) type: NUMERIC width: 5 numdecs: 0 name: ìFIDî
  1) type: FLOAT width: 12 numdecs: 2 name: ìLengthî
  2) type: FLOAT width: 12 numdecs: 2 name: ìAvg_Zî
Number of Shapes: 1
  Shape 0
  Attribute Values:
    0) 1.000000
    1) 499.480000
    2) 246.110000
  Number of Parts: 1
    Part 0
    Number of Points: 7
      0) 477567.790655 4761334.590929 253.274794
0.000000
      1) 477590.949369 4761320.846640 252.083886
0.000000
      2) 477640.467529 4761334.585455 249.732452
0.000000
      3) 477682.994049 4761370.204399 249.981176
0.000000
      4) 477835.599716 4761325.251643 240.026947
0.000000
      5) 477780.959225 4761160.110996 238.303423
```

```
0.000000
      6) 477770.529141 4761129.603740 239.362935
0.000000

Shape Class 7 : ìunmonumentedî
FCode 1002
Shape Type: 3D_POINT
Number of Attributes: 2
  0) type: NUMERIC width: 5 numdecs: 0 name: ìFIDî
  1) type: FLOAT width: 12 numdecs: 2 name: ìAvg_Zî
Number of Shapes: 7
  Shape 0
  Attribute Values:
    0) 1.000000
    1) 252.520000
  Number of Parts: 1
    Part 0
    Number of Points: 1
      0) 477751.157808 4761643.623624 252.523214
0.000000
  Shape 1
  Attribute Values:
    0) 2.000000
    1) 243.360000
  Number of Parts: 1
    Part 0
    Number of Points: 1
      0) 477936.028257 4761520.168603 243.360006
0.000000
  Shape 2
  Attribute Values:
    0) 3.000000
    1) 230.470000
  Number of Parts: 1
    Part 0
    Number of Points: 1
      0) 477960.057966 4761373.735163 230.468465
0.000000
  Shape 3
  Attribute Values:
    0) 4.000000
    1) 250.310000
  Number of Parts: 1
    Part 0
    Number of Points: 1
      0) 477831.987510 4761599.411265 250.306677
0.000000
  Shape 4
  Attribute Values:
    0) 5.000000
    1) 250.220000
  Number of Parts: 1
    Part 0
    Number of Points: 1
      0) 477923.232009 4761651.720452 250.219824
0.000000
  Shape 5
  Attribute Values:
    0) 6.000000
    1) 252.400000
  Number of Parts: 1
    Part 0
    Number of Points: 1
      0) 477692.491579 4761488.963133 252.403413
```

```
0.000000
  Shape 6
  Attribute Values:
    0) 7.000000
    1) 250.040000
  Number of Parts: 1
    Part 0
    Number of Points: 1
      0) 477682.114596 4761405.622751 250.044994
0.000000

Shape Class 10 : ìwoodsî
FCode 7000
Shape Type: 3D_POLYGON
Number of Attributes: 4
  0) type: NUMERIC width: 5 numdecs: 0 name: ìFIDî
  1) type: FLOAT width: 12 numdecs: 2 name: ìAreaî
  2) type: FLOAT width: 12 numdecs: 2 name: ìPerimeterî
  3) type: FLOAT width: 12 numdecs: 2 name: ìAvg_Zî
Number of Shapes: 1
  Shape 0
  Attribute Values:
    0) 1.000000
    1) 8390.510000
    2) 413.790000
    3) 248.160000
  Number of Parts: 1
    Part 0
    Number of Points: 9
      0) 477758.317729 4761553.735138 253.565267
0.000000
      1) 477754.754678 4761532.416856 252.219727
0.000000
      2) 477760.762991 4761502.755170 252.358410
0.000000
      3) 477804.215829 4761494.510509 249.930082
0.000000
      4) 477810.416840 4761487.257458 250.078908
0.000000
      5) 477882.250052 4761475.361479 243.391896
0.000000
      6) 477923.795964 4761499.612660 241.411015
0.000000
      7) 477915.573326 4761525.874234 242.352411
0.000000
      8) 477758.317729 4761553.735138 253.565267
0.000000

End
```

The Stereo Analyst STP DSM

Introduction

Stereo Analyst supports the creation and display of oriented DSMs from external aerial triangulation data (that is, results from performing a bundle block adjustment). Oriented DSMs contain sufficient sensor model and image information to define the relationship between the images in a stereopair, the sensor, and the ground. As a result, the left and right image comprising a stereopair can be displayed in stereo while also providing accurate real-world 3D geographic information.

The Stereo Analyst STP file serves as an ASCII meta-data file that contains all of the necessary information required to display a stereopair and also collect real-world 3D coordinates in stereo. It is important to note that the STP file contains post-processed sensor model information. The images and results from aerial triangulation (that is, interior and exterior orientation) information are first transformed outside of Stereo Analyst to account for the variation in orientation and image XY position for the left and right images comprising a stereopair.

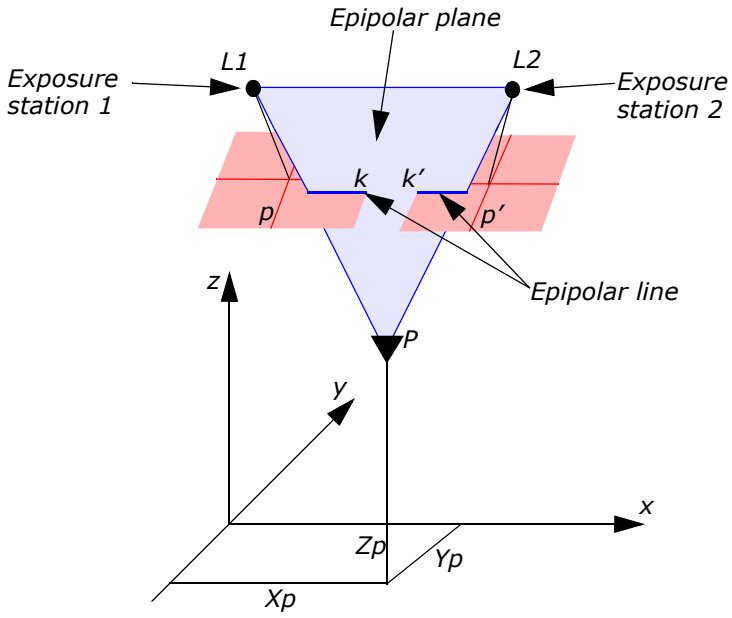
Epipolar Resampling

The transformation procedure is referred to as epipolar resampling. The epipolar resampling procedure resamples the original left and right images using the results from aerial triangulation. As a result, new image coordinate positions are calculated for each image of a stereopair. The original left and right image coordinates and positions are transformed according to their degree of orientation, which is defined as Omega, Phi, and Kappa, and position. The epipolar resampling process minimizes the differences between the left and right image orientation and position. As a result, y-parallax is removed. The remaining parallax is x-parallax. The variation in x-parallax throughout the DSM is proportional to the variation of elevation.

Coplanarity Condition

The epipolar resampling procedure uses the concepts associated with the coplanarity condition. The coplanarity condition states that the two sensor exposure stations of a stereopair, any ground point, and the corresponding image positions on the two images must all lie in a common plane.

Figure 42: Epipolar Geometry and the Coplanarity Condition



Source: Keating, Wolf, and Scarpace 1975

The common plane is also referred to as the epipolar plane. The epipolar plane intersects the left and right images, and the lines of intersection are referred to as epipolar lines. The image positions of a ground point appearing on the left and right photos lie along the epipolar line. The epipolar resampling process transforms the original left and right images so that the image positions of a ground point do lie along a straight line. The image positions of a ground point only lie along a straight line if the varying image orientations and position of each sensor have been considered. Once the left and right images have been resampled, the epipolar line is parallel to the flight line axis.

Using OpenGL software techniques, Stereo Analyst automatically resamples the left and right images of a stereopair, if sensor model information is available. If epipolar resampled imagery has already been created in another photogrammetric product, a Stereo Analyst STP file can be created in order to use the data and information in Stereo Analyst.

STP File Characteristics

The Stereo Analyst STP file contains the following information:

Introductory line. This line is required for each Stereo Analyst STP file. It states that the information in the file reflects epipolar geometry information.

Geometry. The geometry field defines the type of sensor model used. The Stereo Analyst STP file supports frame camera sensor systems only. The frame camera sensor system employs single perspective geometry to capture photography and imagery. The value to be used for this field is FRAME.

Projection Name. The STP file format supports a Cartesian-based projection system. The options include UTM and Cartesian. The projection specified should reflect the projection used to determine the epipolar resampled imagery and exterior orientation information.

See the On-Line Help for more information about projections.

Unit X and Y. The unit X and Y value should reflect the units associated with the X and Y components of exterior orientation for the left and right images.

Unit Z. The unit Z value should reflect the units associated with the Z component of exterior orientation for the left and right images.

Resampling Mode. The resampling mode value indicates which resampling method was used to perform epipolar resampling on the left and right images. A value of 1 is used for nearest neighbor and a value of 2 is used for bilinear interpolation.

Rotation Angle Mode. The rotation angle mode value indicates the type of rotation system used to derive the orientation angles associated with exterior orientation. A value of 1 indicates that the +Phi (about X), Omega (about Y), Kappa (about Z) system was used. A value of 0 indicates that the -Phi (about X), Omega (about Y), Kappa (about Z) system was used. A value of 2 indicates that the Omega (about X), Phi (about Y) and Kappa (about Z) system was used.

Average Flying Height. The average flying height value defines the average altitude above ground level of the sensor as it existed when the image was captured. The units of this value should correspond to the units defined by Unit Z.

Epipolar Focal Length. The epipolar focal length value defines the focal length used during the aerial triangulation process. The units used for the focal length should be the same as the units used for the interior orientation affine transform coefficients.

Output Image File First. The output image file first field defines the name of the left image file. The STP file supports IMG and TIF image files. If the output STP file and the image files are not stored in the same directory, the image name and path must be defined.

Output Image Number First. The output image number first field defines the image ID to be used for the left image comprising the stereopair of interest.

Inner Parameter First. The inner parameter first field defines the six affine coefficients (computed from the epipolar resampling process) associated with the interior orientation of the left image. The units of the coefficients should be equivalent to the units used for the focal length. The affine transform coefficients should be defined according to the image (that is, pixel) to film format.

Outer Parameter First. The outer parameter first field defines the six exterior orientation values for the left image, which are computed from the epipolar resampling process. The units of the positional elements of exterior orientation must be equivalent to the UNIT_X_Y and UNIT_Z definitions.

Output Image File Second. The output image file second field defines the name of the right image file. The STP file supports IMG and TIF image files. If the output STP file and the image files are not stored in the same directory, the image name and path must be defined.

Output Image Number Second. The output image number second field defines the image ID to be used for the right image comprising the stereopair of interest.

Inner Parameter Second. The inner parameter second field defines the six affine coefficients (computed from the epipolar resampling process) associated with the interior orientation of the right image. The units of the coefficients should be equivalent to the units used for the focal length. The affine transform coefficients should be defined according to the image (that is pixel) to film format.

Outer Parameter Second. The outer parameter second field defines the six exterior orientation values for the right image computed from the epipolar resampling process. The units of the positional elements of exterior orientation must be equivalent to the UNIT_X_Y and UNIT_Z definitions.

STP File Example

The following example illustrates the STP file used for a data set.

```
EPIPOLAR_OUTPUT_FILE

GEOMETRY: FRAME

PROJECTION_NAME: UTM

UNIT_X_Y: METER

UNIT_Z: METER

RESAMPLING_MODE: 2

ROTATION_ANGLE_MODE: 2

AVERAGE_FLYING_HEIGHT: 7500.000000

EPIPOLAR_FOCAL_LENGTH: 152.782


OUTPUT_IMAGE_FILE_FIRST:c2rgb50ep.img

OUTPUT_IMAGE_NO_FIRST:12

INNER_PAR_FIRST:-64.768081403 0.050017079 0.0 108.173757261 0.0 -0.050017079

OUTER_PAR_FIRST:426319.7210 3717179.8370 7619.8140 0.0000 -0.0659 147.3785


OUTPUT_IMAGE_FILE_SECOND:c3rgb50ep.img

OUTPUT_IMAGE_NO_SECOND:13

INNER_PAR_SECOND: -115.236231809 0.050017079 0.0 108.173757261 0.0 -0.050017079

OUTER_PAR_SECOND:424013.4810 3718655.9580 7617.1600 0.0000 -0.0659 147.3785
```

References

Introduction

This appendix includes a list of works you may want to read for further information as well as works cited in this document.

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Glossary

Introduction

The following glossary defines terms commonly used in Stereo Analyst.

Numerics

2D. Images or photos in X and Y coordinates only, there is no vertical element (Z) to 2D images. Viewed in mono, 2D images are good for qualitative analysis.

3D. Images or photos in X, Y, and Z (vertical) coordinates. Viewed in stereo, 3D images approximate true Earth features.

3D floating cursor. The 3D floating cursor is apparent when you have a DSM (that is, two images of approximately the same area) displayed in the Digital Stereoscope Workspace. The position of the 3D floating cursor position is determined by the amount of x-parallax evident in the DSM, and your positioning of it on the ground or feature or interest. You adjust the position of the 3D floating cursor using your keyboard and your mouse. See also x-parallax.

3D shapefile. A 3D shapefile is a standard shapefile with the added Z, or elevation dimension. In Stereo Analyst, you can create 3D shapefiles using feature collection tools such as Extend Feature, which extends the corners of a feature (for example, a building) to touch the ground.

Symbols

***.blk.** The .blk extension stands for a block file containing one or more images that can be viewed in stereo. You can use the Stereo Pair Chooser to select a stereopair from a block file.

***.fpj.** The .fpj extension stands for feature project. In an .fpj project, you can collect features in vector format from stereo imagery.

***.stp.** The .stp extension stands for stereopair. An .stp image is made of two images.

κ. Kappa. An angle used to define angular orientation. κ is rotation about the z-axis.

ω. Omega. An angle used to define angular orientation. ω is rotation about the x-axis.

φ. Phi. An angle used to define angular orientation. φ is rotation about the y-axis.

Terms

A

Active tool. In Stereo Analyst, the active tool is the one you are currently using to collect or edit features in a Feature Project. Its active status is indicated by its apparent depression in the Stereo Analyst feature toolbar. The active tool can be locked for repeated use using the Lock tool.

Adjusted stereopair. An adjusted stereopair is a pair of images displayed in a Digital Stereoscope Workspace that has a map projection system associated with it.

Aerial photographs. Photographs taken from vertical or near vertical positions above the Earth captured by aircraft or satellite. Photographs used for planimetric mapping projects.

Aerial triangulation. (AT) The process of establishing a mathematical relationship between images, the camera or sensor model, and the ground. The information derived is necessary for orthorectification, DEM generation, and stereopair creation.

Affine transformation. Defines the relationship between the pixel coordinate system and the image space coordinate system using coefficients.

Air base. The distance between the two image exposure stations. See also Base-height ratio.

Airborne GPS. A technique used to provide initial approximations of exterior orientation, which defines the position and orientation associated with each image as they existed during image capture. See also Global positioning system.

Airborne INS. INS stands for inertial navigation system. Airborne INS data is available for each image, and defines the position and orientation associated with an image as they existed during image capture.

American Standard Code for Information Interchange (ASCII). A "basis of character sets...to convey some control codes, space, numbers, most basic punctuation, and unaccented letters a-z and A-Z" (FOLDOC 1999).

Anaglyph. An anaglyph is a 3D image composed of two oriented or nonoriented stereopairs. To view an anaglyph, you require a pair of red/blue glasses. These glasses isolate your vision into two distinct parts corresponding with the left and right images of the stereopair. This produces a 3D effect with vertical information.

Analog photogrammetry. Optical or mechanical instruments, such as analog plotters, used to reconstruct 3D geometry from two overlapping photographs.

Analytical photogrammetry. The computer replaces some expensive optical and mechanical components by substituting analog measurement and calculation with mathematical computation.

Anti-aliasing. In a DSM, anti-aliasing appears as shimmering effects visible in urban areas due to limited texture mapping.

ASCII. See American Standard Code for Information Interchange.

AT. See Aerial triangulation.

Attribute. An attribute is a piece of information stored by Stereo Analyst about a feature you have collected in the Digital Stereoscope Workspace. For example, if you collect a road feature, attributes associated with that feature include the X, Y, and Z components of each vertex making up the road. Attribute information also includes the total line length. You can add additional attribute information to the feature, such as the name of the road, if you wish.

Attribute table. An attribute table is automatically created when you digitize 3D features using Stereo Analyst. The attribute table appears at the bottom of the Stereo Analyst window in a bucket. Attribute tables contain default information depending on the type of feature they represent. For example, an attribute table detailing road features has a length attribute.

Attribution. Attribution is attribute data associated with a feature. See Attribute.

B

Base-height ratio. The ratio between the average flying height of the camera and the distance between where the two overlapping images were captured.

b/h. See Eye-base to height ratio.

Block file. A block file has the .blk extension. Block files contain at least one stereopair that is in a coordinate system. A block file may also contain two or more sets of stereo images that you can use for feature extraction and viewing. In that case, you can use the Stereo Pair Chooser to select which stereopair of the block file you want to use in analysis.

Block triangulation. The process of establishing a mathematical relationship between images, the camera or sensor model, and the ground. The information derived is necessary for orthorectification, DEM generation, and stereopair creation.

Breakline. An elevation polyline in which each vertex has its own X, Y, Z value.

Bucket. One of three sections located in the lower portion of the Stereo Analyst window. Buckets can contain the 3D Measure tool, the Position tool, and any Attribute Table you want to display. Buckets are populated in the order in which you select tools to work with in Stereo Analyst.

Bundle block adjustment. A mathematical technique that determines the position and orientation of each image as they existed at the time of image capture, determines the ground coordinates measured on overlap areas of multiple images, and minimizes the error associated with the imagery, image measurements, and GCPs.

C

Cache. A temporary storage area for data that is currently in use. The cache enables fast manipulation of the data. When data is no longer held by the cache, it is returned to the permanent storage place for the data, such as the hard drive.

CAD. see Computer-aided design.

Calibration certificate/report. In aerial photography, the manufacturer of the camera specifies the interior orientation in the form of a certificate or report.

CCD. See Charge-coupled device.

Charge-coupled device. (CCD) "A semiconductor technology used to build light-sensitive electronic devices such as cameras and image scanners" (FOLDOC 2000a).

Collinearity. A nonlinear mathematical model that photogrammetric triangulation is based upon. Collinearity equations describe the relationship among image coordinates, ground coordinates, and orientation parameters.

Collinearity condition. The condition that specifies that the exposure station, ground point, and its corresponding image point location must all lie along a straight line.

Computer-aided design. (CAD) Computer application used for design and GPS survey.

Control point extension. This technique requires the manual measurement of ground points on photos of overlapping areas. The ground coordinates associated with the GCPs are then determined by using photogrammetric techniques of analog or analytical stereo plotters.

Coordinate system. A method for expressing location. In 2D coordinate systems, locations are expressed by a column and row, also called X and Y. In a 3D coordinate system, the elevation value is added, called Z.

Coplanarity condition. The coplanarity condition is used to calculate relative orientation. It uses an iterative least squares adjustment to estimate five parameters (B_y, B_z, Omega [ω], Phi [φ], and Kappa [κ]). The parameters explain the difference in position and rotation between the two images making up the stereopair.

Correlate. Matching regions of separate images for the purposes of tie point or GCP collection, as well as elevation extraction.

D

Datum. Defines the height of the camera above sea level.

Degrees of freedom. Also known as redundancy. The number of unknowns is subtracted from the number of knowns. The resulting number is the redundancy, or degree of freedom in a solution.

Delta. Difference, usually in elevation, slope, or degree.

Delta Z. Difference in elevation between points.

DEM. See Digital elevation model.

Digital elevation model. Continuous raster layers in which data file values represent elevation. DEMs are available from the USGS at 1:24,000 and 1:250,000 scale.

Digital orthophoto. An aerial photo or satellite scene that has been transformed by the orthogonal projection, yielding a map that is free of most significant geometric distortions.

Digital photogrammetric workstations. (DPW) These include PCI OrthoEngine, SOCET SET, Intergraph, Zeiss, and others.

Digital photogrammetry. Photogrammetry as applied to digital images that are stored and processed on a computer. Digital images can be scanned from photographs or can be directly captured by digital cameras.

Digital stereo model. (DSM) Stereo models that use imaging techniques of digital photogrammetry that can be viewed on desktop applications, such as Stereo Analyst.

Digital terrain model. (DTM) A DTM is a discrete expression of topography in a data array, consisting of a group of planimetric coordinates (X, Y) and the elevations (Z) of the ground points and breaklines. See also Breakline.

Direction of flight. Images in a strip are captured along the aircraft or direction of flight of the satellite. Images overlap in the same manner as the direction of flight.

Disabled tool. In Stereo Analyst, a disabled tool is a tool that is not available to you based on the operation you are attempting to perform. For example, if you are using the Parallel Line tool to collect a road feature, the Reshape tool is disabled as it has no application at the time you are collecting the feature; however, once you finish collecting the road feature, the Reshape tool becomes enabled. See also Enabled tool.

DLL. See Dynamically loaded libraries.

DPW. See Digital photogrammetric workstations.

DSM. See Digital stereo model.

DTM. See Digital terrain model.

Dynamically loaded library. (DLL) A Dynamically Loaded Library is loaded by the Stereo Analyst application as they are needed. DLLs provide added functionality such as stereo display and import/export capabilities.

E

Earth Observation Satellite Company. (EOSAT) A private company that directs the Landsat satellites and distributes Landsat imagery.

Elements of exterior orientation. Variables that define the position and orientation of a sensor as it obtained an image. It is the position of the perspective center with respect to the ground space coordinate system.

Ellipsoid. "A surface all plane sections of which are ellipses or circles" (Merriam-Webster OnLine Dictionary 2000a).

Enabled tool. An enabled tool is one that is active for your current application. For example, feature collection tools such as the Parallel Line tool are enabled when you are collecting features. If your current application is feature editing, then tools such as the Reshape tool are available to you. See also Disabled tool.

EOSAT. See Earth Observation Satellite Company.

Ephemeris. Data contained in the header of the data file of a SPOT scene, provides information about the recording of the data and the satellite orbit.

Epipolar stereopair. A stereopair without y-parallax.

Exposure station. During image acquisition, each point in the flight path at which the camera exposes the film.

Exterior orientation. All images of a block of aerial photographs in the ground coordinate system are computed during photogrammetric triangulation, using a limited number of points with known coordinates. The exterior orientation of an image consists of the exposure station and the camera attitude at the moment of image capture.

Exterior orientation parameters. The ground coordinates of the perspective center in a specified map projection and three rotation angles around the coordinate axes.

Eye-base to height ratio. (b/h) The eyebase is the distance between a person's eyes. The height is the distance between the eyes and the image datum. When two images of a stereopair are adjusted in the X and Y direction, the b/h ratio is also changed. You change the X and Y positions to compensate for parallax in the images.

F

Feature collection. The process of identifying, delineating, and labeling various types of natural and human-made phenomena from remotely-sensed images.

Feature collection mode. One of the two feature modes in Stereo Analyst is the feature collection mode. In this mode, you are actually collecting features from a DSM displayed in the Digital Stereoscope Workspace. As you collect features, you are adding attribution data to the attribute tables associated with each feature class. See also Feature editing mode.

Feature editing mode. One of the two feature modes in Stereo Analyst is the feature editing mode. In this mode, you use tools to edit features you have already collected from a DSM. As you edit features, their attribute information is updated in the attribute tables. See also Feature collection mode.

Feature extraction. The process of studying and locating areas and objects on the ground and deriving useful information from images.

Feature ID. (FID) Each feature in a feature project has its own ID number, which enables you to identify and select it individually.

Feature Project. A Feature Project contains all the feature classes and their corresponding attribute tables you need to create features in your stereo views.

FID. See Feature ID.

Fiducial center. The center of an aerial photo.

Fiducial marks. Four or eight reference markers fixed on the frame of an aerial metric camera and visible in each exposure. Fiducials are used to compute the transformation from data file to image coordinates.

Floating mark. Two individual cursors, one for the right image of the stereopair and one for the left image of the stereopair. When the stereopair is viewed in stereo, the two floating marks display as one when x-parallax is reduced.

Focal length. The distance between the optical center of the lens and where the optical axis intersects the image plane. Focal length of each camera is determined in a laboratory environment.

G

GCP. See Ground control point.

Geocentric. A coordinate system with its origin at the center of the Earth ellipsoid. The Z-axis equals the rotational axis of the Earth, the X-axis passes through the Greenwich meridian, and the Y-axis is perpendicular to both the Z-axis and the X-axis so as to create a 3D coordinate system that follows the right-hand rule.

Geocorrect. A method of establishing a geometric relationship between imagery and the ground. Geocorrection does not use many GCPs, and is therefore not as accurate as orthocorrection, or orthorectification. See also Orthorectify.

Geolink. A method of establishing a relationship between attribute data and the features they pertain to.

Global Positioning System. (GPS) "A system for determining position on the Earth's surface by comparing radio signals from satellites" (FOLDOC 2000b).

GPS. See Global Positioning System.

Ground control point. (GCP) A specific pixel in image data for which the output map coordinates (or other output coordinates) are known. GCPs are used for computing a transformation matrix, for use in rectifying an image.

Ground coordinate space. A coordinate system used by oriented stereopairs. Ground coordinate space relates directly to the surface of the Earth. Measurements in ground coordinate space are 3D, including length, width, and elevation values.

Ground coordinate system. A 3D coordinate system that utilizes a known map projection. Ground coordinates (X, Y, and Z) are usually expressed in feet or meters.

Ground space. Events and variables associated with the objects being photographed or imaged, including the reference coordinate system.

H

Header file. A portion of a sensor-derived image file that contains ephemeris data. The header file contains all necessary information to determine the exterior orientation of the sensor at the time of image acquisition.

I

Image coordinate space. The coordinate system used by nonoriented stereopairs. It is a 2D space where measurements are recorded in pixels.

Image scale. (SI) Expresses the ratio between a distance in the image and the same distance on the ground.

Image space. Events and variables associated with the camera or sensor as it acquired the images. The area between perspective center and the image.

Inactive tool. An inactive tool is a tool that is enabled, but is not in use. It appears unshaded (denoting its enabled status) in the Stereo Analyst feature toolbar, but is not depressed, which indicates an active tool. See also Active tool.

Indian Remote Sensing Satellite. (IRS) Satellites operated by Space Imaging, including IRS-1A, IRS-1B, IRS-1C, and IRS-1D.

Inertial navigation system. (INS) A technique that provides initial approximations to exterior orientation.

INS. See Inertial navigation system.

Interior orientation. Defines the geometry of a sensor that captured an image. This information is defined in fiducial marks in the case of cameras. Definition of the light rays passing from the perspective center through the image plane and onto the ground (Moffit and Mikhail 1980).

International Society of Photogrammetry and Remote Sensing. (ISPRS) An organization "devoted to the development of international cooperation for the advancement of photogrammetry and remote sensing and their application." For more information, visit the web site at http://www.isprs.org (ISPRS 2000).

IRS. See Indian Remote Sensing Satellite.

ISPRS. See International Society of Photogrammetry and Remote Sensing.

K

Kappa. (κ) A measurement used to define camera or sensor rotation in exterior orientation. Kappa is rotation about the photographic z-axis.

L

Landsat. A series of Earth-orbiting satellites that gather imagery. Operated by EOSAT.

Least squares adjustment. A technique used to determine the most probable positions of exterior orientation. The least squares adjustment technique reduces error.

Lens distortion. Caused by the instability of the camera lens at the time of data capture. Lens distortion makes the positional accuracy of the image points less reliable.

Line of sight. (LOS) Area that can be viewed along a straight line without obstructions.

Line segment. The area between vertices of a polyline or polygon. Line segments can be edited and deleted using Stereo Analyst feature editing tools.

Linear interpolation. Data file values are plotted in a graph relative to their distances from one another, creating a visual linear interpolation.

Lithological. Relating to rocks.

LOS. see Line of sight.

M

Map coordinate system. A map coordinate system that expresses locations on the surface of the Earth using a particular map projection such as Universal Transverse Mercator (UTM), State Plane, or Polyconic.

Metric photogrammetry. The process of measuring information from photography and satellite imagery.

Mono. A mono view is that in which there is only one image. There are not two images to create a stereopair. You cannot see in 3D using a mono view.

Mosaicking. The process of piecing together images, side by side, to create a larger image.

Multiple points. Multiple points can be collected from a DSM to create a TIN or DEM. Like a single point, multiple points have X, Y, and Z coordinate values. See also TIN and DEM.

N

Nadir. The area on the ground directly beneath the detectors of a scanner.

Nearest neighbor. A resampling method in which the output data file value is equal to the input pixel whose coordinates are closest to the retransformed coordinates of the output pixel.

Nonoriented stereopair. A nonoriented stereopair is made up of two overlapping photographs or images that have not been photogrammetrically processed. Neither the interior nor the exterior orientation, which define the internal geometry of the camera of the sensor as well as its position during image capture, has been defined. You can collect measurements from a nonoriented stereopair; however, the measurements are in pixels and 2D.

Nonorthogonality. The degree of variation between the x-axis and the y-axis.

O

Object space coordinate system. The origin is defined by the projection, spheroid, and datum of the area being imaged.

Oblique photographs. Photographs captured by an aircraft or satellite deliberately offset at an angle. Oblique photographs are usually used for reconnaissance and corridor mapping applications.

Off-nadir. Any point that is not directly beneath the detectors of a scanner, but off to an angle. The SPOT scanner allows off-nadir viewing.

Omega. (ω) A measurement used to define camera or sensor rotation in exterior orientation. Omega is rotation about the photographic x-axis.

OpenGL. OpenGL is a development environment that allows stereopairs to be displayed in a stereo view in 3D space. For more information, visit the web site www.opengl.org.

Orientation matrix. A three-by-three matrix defining the relationship between two coordinate systems (that is, image space coordinate system and ground space coordinate system).

Oriented stereopair. An oriented stereopair has a known interior (camera or sensor internal geometry) and exterior (camera or sensor position and orientation) orientation. The y-parallax of an oriented stereopair has been improved. Additionally, an oriented stereopair has geometric and geographic information concerning the surface of the Earth and a ground coordinate system. Features and measurements taken from an oriented stereopair have X, Y, and Z coordinates.

Orthorectification. A photogrammetric technique used to eliminate errors in DSMs efficiently, which allows accurate and reliable information. LPS Project Manager makes use of orthorectification to obtain a high degree of accuracy.

Overlay. 1. A function that creates a composite file containing either the minimum or the maximum class values of the input files. Overlay sometimes refers generically to a combination of layers. 2. The process of displaying a classified file over the original image to inspect the classification.

OverView. In an OverView, you can see the entire DSM displayed in a stereo view. OverViews can render DSMs in both mono and stereo.

P

Paging. When data is read from the hard disk into main memory, it is referred to as paging. The term paging originated from blocks of disk data being read into main memory in fixed sizes called pages. Dynamic paging brings manageable subsets of a large data set into the main memory.

Parallactic angle. The resulting angle made by eyes focusing on the same point in the distance. The angle created by intersection.

Parallax. Displacement of a ground point appearing in a stereopair as a function of the position of the sensors at the time of image capture. You can adjust parallax in both the X and the Y direction so that the image point in both images appears in the same image space.

Perspective center. 1. A point in the image coordinate system defined by the x and y coordinates of the principal point and the focal length of the sensor. 2. After triangulation, a point in the ground coordinate system that defines the position of the sensor relative to the ground.

Phi. (φ) A measurement used to define camera or sensor rotation in exterior orientation. Phi is rotation about the photographic y-axis.

Photogrammetric quality scanners. Special devices capable of high image quality and excellent positional accuracy. Use of this type of scanner results in geometric accuracy similar to traditional analog and analytical photogrammetric instruments.

Photogrammetry. The "art, science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant imagery and other phenomena" (American Society of Photogrammetry 1980).

Pixel. Abbreviated from "picture element;" the smallest part of a picture (image).

Point. A point is a feature collected in Stereo Analyst that has X, Y, and Z coordinates. A point can represent a feature such as a manhole cover, fire hydrant, or telephone pole. You can collect multiple points for the purposes of creating a TIN or DEM.

Polygon. A polygon is a set of closed line segments defining an area, and is composed of multiple vertices. In Stereo Analyst, polygons can be used to represent many features, from a building to a field, to a parking lot. Additionally, polygons can have an added elevation value.

Polyline. A polyline is an open vector attribute made up of two or more vertices. In a DSM, polylines have X, Y, and Z coordinates associated with them.

Principal point (Xp, Yp). The point in the image plane onto which the perspective center is projected, located directly beneath the interior orientation. The origin of the coordinate system. Where the optical axis intersects the image plane.

Pushbroom. A scanner in which all scanning parts are fixed and scanning is accomplished by the forward motion of the scanner, such as the SPOT scanner.

Pyramid layer. A pyramid layer is an image layer that is successively reduced by a power of 2 and resampled. Pyramid layers enable large images to be displayed faster in the stereo views at any resolution.

R

Radial lens distortion. Imaged points are distorted along radial lines from the principal point. Also referred to as symmetric lens distortion.

Raw stereopair. A raw stereopair is a stereopair displayed in a stereo view that does not have a map projection system associated with it. However, because the images are of the same relative area, they can be displayed in a stereo view.

Reference coordinate system. Defines the geometric characteristics associated with events occurring in object space. Also referred to as the object space coordinate system.

Rendering. An image is rendered in the stereo view when it is redrawn at the scale indicated by the zoom in or out factor. Rendering is another term for drawing the image in the stereo view.

Right hand rule. A convention in 3D coordinate systems (X,Y,Z) that determines the location of the positive Z-axis. If you place your right hand fingers on the positive X-axis and curl your fingers toward the positive Y-axis, the direction your thumb is pointing is the positive Z-axis direction.

RMSE. See Root Mean Square Error.

Root Mean Square Error. (RMSE) Used to measure how well a specific calculated solution fits the original data. For each observation of a phenomena, a variation can be computed between the actual observation and a calculated value. (The method of obtaining a calculated value is application-specific.) Each variation is then squared. The sum of these squared values is divided by the number of observations and then the square root is taken. This is the RMSE value.

Rubber sheeting. A 2D rectification technique (to correct nonlinear distortions), which involves the application of a nonlinear rectification (2nd-order or higher).

S

Scene. In Stereo Analyst, a scene is made up of the stereo view and the data layers, including any features, that are displayed in the stereo view. A scene can be in either mono or stereo. The four major features of a scene are the stereo view, a menu bar, a toolbar, and a status message bar.

Screen digitizing. The process of drawing vector graphics on the display screen with a mouse.

Self-calibration. A technique used in bundle block adjustment to determine internal sensor model information.

Sensor. A device that gathers energy, converts it to a digital value, and presents it in a form suitable for obtaining information about the environment.

Shapefile. A shapefile is an ESRI vector format that contains spatial data. This data is recorded in Stereo Analyst in the form of attributes in an attribute table. These attributes include X and Y coordinates. Multiple shapefiles can be saved in one Stereo Analyst Feature Project. See also Vector.

SI. See Image scale.

Single frame orthorectification. Orthorectification of one image at a time using the space resection technique. A minimum of 3 GCPs is required for each image.

Space intersection. A technique used to determine the ground coordinates X, Y, and Z of points that appear in the overlapping areas of two images, based on the collinearity condition.

Space resection. A technique used to determine the exterior orientation parameters associated with one image or many images, based on the collinearity condition.

SPOT. A series of Earth-orbiting satellites operated by the Centre National d'Etudes Spatiales (CNES) of France.

Stereo. A stereo view is that in which there are two images that form a stereopair. A stereopair can either be raw (without coordinates) or adjusted (with coordinates).

Stereo Pair Chooser. A dialog that enables you to choose stereopairs from a block file.

Stereo model. Three-dimensional image formed by the brain as a result of changes in depth perception and parallactic angles. Two images displayed in a Digital Stereoscope Workspace for the purpose of viewing and collecting 3D information.

Stereopair. A set of two remotely-sensed images that overlap, providing a 3D view of the terrain in the overlap area.

Stereo scene. Achieved when two images of the same area are acquired on different days from different orbits, one taken east of the vertical, and the other taken west of the nadir.

Strip of photographs. Consists of images captured along a flight-line, normally with an overlap of 60% for stereo coverage. All photos in the strip are assumed to be taken at approximately the same flying height and with a constant distance between exposure stations. Camera tilt relative to the vertical is assumed to be minimal.

T

Tangential lens distortion. Distortion that occurs at right angles to the radial lines from the principal point.

Terrestrial photographs. Ground-based photographs and images taken with a camera stationed on or near the surface of the Earth. Photographs are usually used for archeology, geomorphology, and civil engineering.

Texels. Texture pixels used to determine filtering and texturing. Screen pixels per texture pixels.

Texture map. A chunk of image data that can be warped and stretched in three dimensions to fit a set of coordinates specified for the corners.

Theodolites. "A surveyor's instrument for measuring horizontal and usually also vertical angles" (Merriam-Webster OnLine Dictionary 2000b).

Three-dimensional. See 3D.

Tie point. A point whose ground coordinates are not known, but can be recognized visually in the overlap or sidelap area between two images.

TIN. see Triangulated Irregular Network.

Topocentric. A coordinate system that has its origin at the center of the image projected on the Earth ellipsoid. The three perpendicular coordinate axes are defined on a tangential plane at this center point. The plane is called the reference plane of the local datum. The x-axis is oriented eastward, the y-axis northward, and the z-axis is vertical to the reference plane (up).

Transparency. Transparency is used in traditional photogrammetry techniques as a method of collecting features. It is a clear cover placed over two images which form a stereopair. Then, features are hand-drawn on the transparency, and can then be transferred to digital format by scanning or digitizing. A brand of transparency is Mylar®.

Triangulated Irregular Network. (TIN) A TIN enables you to collect TIN points and create breaklines in an image displayed in a stereo view. A TIN is a type of DEM that, unlike a raster grid-based model, allows you to place points at varying intervals.

Triangulation. Establishes the geometry of the camera or sensor relative to objects on the surface of the Earth.

Two-dimensional. See 2D.

U

United States Geological Survey. (USGS) An organization dealing with biology, geology, mapping, and water. For more information, visit the web site www.usgs.gov.

USGS. See United States Geological Survey.

V

Vertex. A vertex is a component of a feature digitized in the Digital Stereoscope Workspace. A vertex is made up of three axes: X, Y, and Z. The Z component corresponds to the elevation of the vertex. A feature can be composed of only one vertex (that is, a point as in a TIN) or many vertices (that is, a polyline or polygon). You can adjust the X, Y, and Z components of an existing vertex. See also Point, Polyline, and Polygon.

Vertical exaggeration. The effect perceived when a DSM is created and viewed. Vertical exaggeration is also referred to as relief exaggeration, and is the evidence of height differences in a stereo model.

Vertices. A polyline or polygon is composed of multiple vertices. These vertices, like a single vertex, have X, Y, and Z components. You can adjust the X and Y component of vertices of a polyline or polygon by using feature editing tools such as Reshape. You can also add a vertex or vertices to an existing feature. To edit the Z component, use the C key on the keyboard. See also Vertex.

W

Workspace. A Digital Stereoscope Workspace is where you complete digital mapping tasks. The Digital Stereoscope Workspace allows you to view stereo imagery and collect 3D features from stereo imagery.

X

X-parallax. The difference in position of a common ground point appearing on two overlapping images, which is a function of elevation. X-parallax is measured horizontally. X- parallax is required to measure elevation, and cannot be completely removed from a stereopair.

Y

Y-parallax. The difference in position of a common ground point appearing on two overlapping images, which is caused by differences in camera position and rotation between two images.Y-parallax is measured vertically.

Z

Z. The vertical (height) component of a vertex, floating cursor, or feature.

Index

Symbols

*.blk (Block file) 275
*.dbf (Database file) 241
*.fcl (Feature class file) 241
*.fpj (Feature project file) 241, 275
*.prj (Projection file) 241
*.rrd (Pyramid layer file) 102
*.shp (Shapefile) 241
*.shx (Index file) 241
*.stp (Stereopair) 275

Numerics

2D 275
2D affine transformation 45
3D 275
3D Extend icon 9
3D floating cursor 69, 275
3D geographic imaging 20
3D Measure Tool icon 7
3D shapefile 275

A

Accuracy check 129
Active tool 276
Add Element icon 9
Adjusted stereopair 276
Aerial photographs 34, 276
Aerial triangulation (AT) 53, 276
Affine transformation 276
Affine transformation coefficients 112
Air base 276
Airborne GPS 53, 58, 276
Airborne INS 58, 276
American Standard Code for Information Interchange 255, 276
Anaglyph 276
Analog photogrammetry 32, 276
Analytical photogrammetry 32, 276
Anti-aliasing 277
ASCII 255
AT 53
Attribute 277
Attribute table 277
Attribution 277
Automated DTM extraction 24
Automated Terrain Following 70
Autopan buffer 156, 208
Average flying height 120, 265

B

b/h 280
Base-height ratio 277
Bilinear interpolation 265
Block file 277
Block triangulation 53, 277
Box Feature icon 8
Breaklines 277
Bucket 277
Bundle block adjustment 24, 53, 277
    definition 53

C

Cache 278
CAD 278
Calibration certificate/report 23, 112, 278
CCD 278
Charge-coupled device 278
Choose Stereopair icon 6
Clear View icon 6
Collect features 171
Collinearity 278
Collinearity condition 50, 278
Collinearity equations 55
Computer-aided design 278
Control point extension 278
Convergence value 58
Coordinate system 40, 278
    ground space 40
    image space 40
Coplanarity condition 263, 278
Copy icon 8
Correlate 278
Create custom feature class 175
Create DSM 111
Create Stereo Model icon 7
Cursor Tracking icon 6
Custom feature class 175
Cut icon 8

D

Datum 278
dBase 241
Degrees of freedom 56, 278
Delta 278
Delta Z 147, 278
DEM 278, 279
Desktop scanners 38
Digital elevation model 279
Digital orthophoto 279
Digital photogrammetric workstations 279
Digital photogrammetry 21, 33, 279
Digital stereo model 279

Digital terrain model 279
Direction of flight 35, 279
Disabled tool 279
DLL 4, 279
DPW 279
DSM creation 111
DTM 279
Dynamically Loaded Library (DLL) 4, 279

E

Earth Observation Satellite Company 279
Edit features 171
Elements of exterior orientation 47, 279
Ellipsoid 279
Enabled tool 280
EOSAT 279, 280
Ephemeris 279, 280
Epipolar
  focal length 265
  line 264
  plane 264
  resampling 263
  resampling on the fly 68
  stereopair 280
Exposure station 36, 280
Exterior orientation 47, 280
Exterior orientation parameters 280
Eye-base to height ratio 280

F

FCODE 255
Feature collection 280
Feature collection mode 280
Feature editing mode 280
Feature extraction 280
Feature ID 280
Feature project 281
Features
  collecting and editing 171
Fiducial 281
  center 281
  marks 45
Fit Scene icon 6
Fixed Cursor Mode icon 7
Flight path 36
Floating mark 281
Focal length 44, 281
Focal plane 44

G

GCP 281
Geocentric 281
  coordinate system 42
  coordinates 42
Geocorrect 281
Geolink 14, 281
Geometric Properties icon 7
Geometry 264
Global Positioning System 281
GPS 281
Ground control point (GCP) 281
Ground coordinate space 281
Ground coordinate system 42, 281
Ground space 40, 281
Ground-based photographs 34

H

Header file 282

I

Icons
  3D Extend 9
  3D Measure Tool 7
  Add Element 9
  Box Feature 8
  Choose Stereopair 6
  Clear View 6
  Copy 8
  Create Stereo Model 7
  Cursor Tracking 6
  Cut 8
  Fit Scene 6
  Fixed Cursor Mode 7
  Geometric Properties 7
  Image Information 6
  Invert Stereo 7
  Left Buffer 8
  Lock 8
  New 6
  Open Workspace 6
  Orthogonal 8
  Parallel 9
  Paste 8
  Polygon Close 9
  Polyline Extend 9
  Position Tool 7
  Remove Segments 9
  Reshape 9
  Revert to Original 6
  Right Buffer 8
  Rotate 8
  Save 6
  Select Element 9
  Streaming 9
  Unlock 8
  Update Scene 7

Zoom one to one 6
Image coordinate space 282
Image coordinate system 41
Image Information icon 6
Image scale 36, 282
Image space 40, 45, 282
coordinate system 41
Inactive tool 282
Indian Remote Sensing Satellite 282
Inertial navigation system 282
Inner parameter first 265
Inner parameter second 266
INS 53, 282
Interior Affine Type 121
Interior orientation 44, 282
International Society of Photogrammetry and Remote Sensing 282
Interpretative photogrammetry 34
Introductory line 264
Invert Stereo icon 7
IRS 282
ISPRS 282

K

Kappa 43, 49, 275, 282

L

Landsat 282
Least squares adjustment 53, 56, 282
Least squares condition 57
Left Buffer icon 8
Lens distortion 46, 283
Line of sight 283
Line segment 283
Linear interpolation 283
Lithological 283
Lock icon 8
LOS 283

M

Map coordinate system 283
Measure features 147
Metric photogrammetry 34, 283
Model space coordinate system 283
Mono 283
Mosaicking 16, 17, 24, 283
Multiple points 283

N

Nadir 283
Nearest neighbor 265, 283
New icon 6
Nonoriented
DSM 75
stereopair 283
Nonorthogonality 46, 283

O

Object space coordinate system 283
Oblique photographs 34, 284
Observation equations 55
Off-nadir 284
Omega 43, 49, 275, 284
Open Workspace icon 6
OpenGL 68, 284
Orient the DSM 88
Orientation 49
matrix 284
Oriented stereopair 284
Orthogonal icon 8
Orthorectify 284
Outer parameter first 266
Outer parameter second 266
Output
image file first 265
image file second 266
image number first 265
image number second 266
Overlay 284
Overview viewer 284

P

Paging 284
Parallactic angle 284
Parallax 284
Parallel icon 9
Paste icon 8
Perspective center 41, 285
Phi 43, 49, 275, 285
Photogrammetric
configuration 54
quality sensors 285
scanners 37
Photogrammetry 31, 285
Photographic base 88
Pixel 285
Pixel coordinate system 40, 45
Plane table photogrammetry 32
Planimetric information 32
Point 285
Polygon 285
Polygon Close icon 9
Polyline 285
Polyline Extend icon 9
Position Tool icon 7

Principal point 41, 44, 89, 285
Projection name 265
Pushbroom 285
Pyramid layer 79, 285

R

Radial lens distortion 46, 47, 285
Raw stereopair 286
RDX file 241
Reference coordinate system 286
Reference plane 42
Relief exaggeration 288
Remove Segments icon 9
Rendering 286
Resampling mode 265
Reshape icon 9
Resolution 38
Revert to Original icon 6
Right Buffer icon 8
Right hand rule 42, 286
RMS error 46
RMSE 38, 286
Root Mean Square Error (RMSE) 38, 46, 286
Rotate icon 8
Rotate the DSM 88
Rotation
    angle mode 265
    matrix 49
Rubber sheeting 16, 286

S

Save icon 6
Scanning resolutions 38, 39
Scene 286
Screen digitizing 286
Select Element icon 9
Select icon
    Icons
        Select 8
Self-calibration 23, 286
Sensor 286
Sensor model 23
Shapefile 286
SI 286
Single frame orthorectification 287
Softcopy photogrammetry 33
Space
    forward intersection 52
    intersection 287
    resection 51, 287
SPOT 287
Stereo 287
Stereo model 287
Stereo Pair Chooser 287
Stereo scene 287
Stereopair 287
Stereoscopic
    parallax 64
    viewing 61
STP file
    average flying height 265
    epipolar focal length 265
    geometry 264
    inner parameter first 265
    inner parameter second 266
    introductory line 264
    outer parameter first 266
    outer parameter second 266
    output image file first 265
    output image file second 266
    output image number first 265
    output image number second 266
    projection name 265
    resampling mode 265
    rotation angle mode 265
    unit X and Y 265
    unit Z 265
Streaming icon 9
Strip of photographs 287
Symmetric lens distortion 47

T

Tangential lens distortion 46, 287
Terrestrial photographs 34, 42, 287
Texels 287
Texture map 287
Theodolites 287
Tie point 288
TIN 288
Topocentric 288
    coordinate system 42
    coordinates 42
Topographic information 32
Transparency 288
Triangulated Irregular Network (TIN) Project 288
Triangulation 288

U

Unit X and Y 265
Unit Z 265
United States Geological Survey 288
Unlock icon 8
Update Scene icon 7
USGS 288

V

V residual matrix 58
Vertex 288
Vertical exaggeration 288
Vertices 288

W

Workspace 289

X

X matrix 57
Xp, Yp 285
X-parallax 289

Y

Y-parallax 289

Z

Zoom one to one icon 6